LAND SUITABILITY EVALUATION USING GIS FOR VEGETABLE CROPS IN KATHMANDU VALLEY /NEPAL

Dissertation

zur Erlangung des akademischen Grades
Doctor rerum agriculturarum
(Dr.rer.agr.)

eingereicht an der
Landwirtschaftlich-Gärtnerischen Fakultät
der Humboldt-Universität zu Berlin

von

M.Sc. Nabarath Baniya
geboren am 01.12.1969 in Kathmandu, Nepal

dem
Präsident der Humboldt-Universität zu Berlin
Prof. Dr. Christoph Markschies

Dekan der Landwirtschaftlich-Gärtnerischen Fakultät
Prof. Dr. Dr. N.c. Otto Kaufmann

Gutachter:
Prof. Dr. sc Drs. h. c. Michael H. Böhme
Dr. rer. agr. Michael La Rosa Perez

Berlin, 13. Oktober 2008

Dedication

To my parents,
Udaya Bahadur Baniya and *Til Kumari Baniya,*
who would have appreciated seeing it if they were still alive.

ACKNOWLEDGEMENT

I wish to express my gratitude to all those who have given me assistance, help and support during the completion of my PhD in Faculty of Agriculture and Horticulture, Institute of Horticultural Sciences, Humboldt University of Berlin.

I acknowledge a deep sense of gratitude to Prof. Dr. Michael Böhme my supervisor, who had always spread his helping hands during my PhD study periods, and given me guidance, valuable suggestion, critical comments and kindness during and completion of present work. His innovative research ideas kind patient and effective guidance throughout my work need not to be exaggerated. This thesis would never be accomplished in this shape without his selfless contributions in various aspects. I am very happy to state that I got to learn a lot from his experience in field of horticulture science.

I gratefully acknowledge Dr. rer. agr. Michael La Rosa Perez, LGF, WISOLA, for guiding me on analytical aspect of the present dissertation. GIS tool is the crux of my study, is accomplished with his tireless help. Thanks to Dr. Ina Pinker for constant inspiration and supportive remarks for the completion of this thesis.

My appreciation is extended to Mr. Mirko Houseworth, a good friend of mine for his valuable support in GIS work and to Dr. Shyam Pathak for appreciable help in text arrangements.

I am very much thankful to all my family members who always support me to pursue my goal. My sincere gratitude goes to my late parents and parents in law for their support. My daughters Ahushuya and Awantika and son Abhinav are also equally thankful for being patient and supportive when I was away from them during my study periods. Finally, very special thanks to my beloved wife Saroja for her support and understanding during my absence and taking care of household matters in the most unfortunate situation ever come in my life. Her inspirational remarks led me toward this path of the achievement. Her support in my achievement is always immense.

I am very indebted to my late parents, mother Til Kumari Baniya and Father Udaya Bahadur Baniya, who were much interested to see my PhD in their life time. They were the crux of my encouragement and achievement. I wish to offer sincere thanks to my elder brothers Mr. Dasharath Baniya and Bhagirath Baniya from whom; I received positive and supportive inspiration that led me to materialize my goal.

At last, my colleagues, Chuong (Vietnam), Ida Asranti (Indonesia) who helped in one way or the other while working together in institute. I thank them from core of my heart..

Finally, I am grateful to the members and staff of Institute of horticulture, Lentzaalee 75 for their timely cooperation.

N. Baniya
Institute of Horticutural Scienc
Faculty of Agriculture and Horticulture
Humboldt University zu Berlin
Berlin
Germany

Berlin, July 2008

ABSTRACT

Kathmandu is a valley situated in hilly area of central Nepal. It has high population density and ever increasing food demand. Land capabilities and cultivation potential seems diminishing. This could results negative consequences to environment and livelihood of Kathmandu dwellers as well. Therefore, research hypothesized that, if land suitability evaluation in wider range is performed, production potential and production of the land would be revitalized. Multi-criteria land suitability evaluation of Kathmandu valley for vegetable crop is felt necessary for the sustainable land use and better vegetable production. So, a main objective of this study is to classify available agricultural land area of Kathmandu valley into different suitable classes for vegetable crop cultivation. Field level information has been gathering through different possible sources. Main spatial and non spatial data were obtained through field work, literature review, expert opinions, interviews of local farmers, professional agencies and other information from the local authorities. Blending up of bottom-up and Top-down approach for decision making process results very positively. Methodology follows the guidelines prepared by FAO (1976) and later version. Considering environmental condition, social parameters and economic indicators are subjected to basic data sources analysis because of the unique social and economic status in Kathmandu valley. This is an approach for site specific modification of the FAO guideline (1976). Analytical part begins with development of Land information System (LIS), which is computer aided GIS based data management. Built up area and non-agriculture were omitted from the analysis. Suitability evaluation was carried out in two different phases, namely 1) Physical land suitability evaluation and 2) Socio-economic-infrastructural land evaluation. From the GIS data, Kathmandu valley still shows the area of 23519ha of potential land for agricultural of which only 1.33 percent land is unsuitable. Currently no land units are highly suitable (S1) and 31 percent and 66 percent area are falls in the category of S2 and S3 respectively. If land condition is improved and updated from current physical suitability with appropriate management input, potential land suitability will be achieved. So, 17.3 percent, 38.6 percent and 42.6 percent area computed as potentiality suitability class of S1, S2 and S3 respectively. Each land mapping unit is bases for the suitability analysis which collectively makes the overlaying thematic maps in GIS tool. Result from the physical land suitability subject to make combined with socioeconomic land suitability evaluation. Together research identifies 15 challenging sub-criteria from three main criteria. This is the fundamental aspect

of multi-criteria land suitability evaluation where economic and social dimension is incorporated into GIS technical tool. For ranking and important judgment of the sub-criteria, pair-wise comparison using AHP process was carried out. The total out put is portrayed in the thematic map of the Kathmandu valley. In this case physical land evaluation includes parameter that satisfy requirement of the vegetable crops and multi-criteria analysis evaluated social and economic indicators of Kathmandu valley. Final result of the multi-criteria land suitability evaluation of Kathmandu valley show that more than 90 percent land area can hold good vegetable cultivation. Together they can meet little above 70 percent demand of the Kathmandu valley. So, result of this study hast to communicate to farmers to make full use of land potential for the development of vegetable cultivation.

Furthermore, LIS prepared in this research could lead to make analysis for other agricultural crops in Kathmandu. At the same time, this model can also be expanded in other parts of country for better land management purpose. From the result, multi-criteria Land suitability evaluation with the use of GIS and AHP is appropriate methodology in the countries like Nepal. However in Nepal, availability of the up-to-date data information is problem that cause building the LIS database is difficult task. Therefore it is recommended from the research to set a panel for gathering and updating reliable and consistent data, both spatial and attribute data. It is also concluded that besides, governmental organisation, INGOs and NGOs involved in this field needs to contribute on managing information and data and also the software systems.

ZUSAMMENFASSUNG

Kathmandu befindet sich in einem Tal in der Gebirgsregion Zentral-Nepals. Bedingt durch die hohe Bevölkerungsdichte gibt es eine steigende Nachfrage nach Lebensmitteln. Die Ressourcen des Landes und der potenzielle Ertrag scheinen demgegenüber aber abzunehmen. Ein Resultat sind negative Auswirkungen auf die Umwelt und die Existenzgrundlage der Bewohner dieser Region. Aus diesem Grund ist die Hypothese dieser Arbeit, dass durch eine großmaßstäbige Untersuchung der Bodenbeschaffenheit das Produktionspotenzial und damit die Produktion des Landes erhöht werden kann. Eine Evaluation nach entscheidungstheoretischen Ansätzen des Kathmandu-Tals im Hinblick auf den Gemüseanbau erscheint unter dem Aspekt einer nachhaltigen Landnutzung und einer erhöhten Gemüseproduktion notwendig. So ist ein entscheidender Ansatz dieser Arbeit, die verfügbaren Anbauflächen im Kathmandu-Tal in verschiedene Eignungsklassen für den Gemüseanbau zu klassifizieren. Informationen über Zustand und Wert der Anbauflächen wurden aus verschiedensten möglichen Quellen zusammengestellt. Grundsätzliche räumliche und nicht-räumliche Daten wurden durch eigene Erhebungen, Literaturrecherche, Expertenmeinungen, Interviews lokaler Bauern, professionellen Beratungsunternehmen und anderer Informationen der lokalen Behörden erfasst. Durch die Mischung eines "bottom-up" bzw. "top-down" Ansatzes für den Entscheidungsfindungsprozess wurden positive Resultate erzielt. Die Methode folgte den Vorgaben der FAO (1976) und den nachfolgenden Fassungen. Unter Berücksichtigung der einzigartigen sozialen und ökonomischen Bedingungen im Kathmandu-Tal beziehen sich der Zustand der Umwelt, die sozialen Parametern und ökonomischen Indikatoren die Untersuchung auf Basisdaten der Region. Der Anspruch ist eine Modifikation der FAO Richlinie (1976). Der analytische Teil beginnt mit der Entwicklung eines Landesinformationssystems (LIS), einem coputergestütztens, GIS-basierten System. Bebaute und nicht agrarisch genutzte Gebiete wurden bei der Untersuchung ausgelassen. Die Evaluation der Beschaffenheit wurde in zwei Phasen durchgeführt, namentlich 1) einer Betrachtung der Bodenfruchtbarkeit 2) einer Evaulation der Sozio-ökonomischen Infrastruktur. Nach einer GIS-Analyse existieren im Kathmandu-Tal eine Fläche von 23.519ha potenzielles Ackerland, von dem lediglich 1.33% nicht nutzbar sind. Gegenwertig ist keine Region im hohen Maße fruchtbar (S1) und 31% bzw. 66% der Region fallen in die Kategorien S2 respektive S3. Eine potenzielle hohe Bodenfruchtbarkeit kann dadurch erreicht werden, wenn der Bodenzustand durch geeignete Mittel verbessert werden kann. Unter diesem Gesichtspunkt konnten 17.3%, 38.6% bzw.

42.6% des Gebiets mit Hilfe geostatistischer Analysen potenziell den Bodenklassen S1, S2 und S3 zugeordnet werden. Jeder einzelne thematische Layer war Basis für eine Fruchtbarkeitsanalyse mittels einer räumlichen Überdechung mit Hilfe verschiedener GIS-Werkzeuge. Die Ergebnisse dieser Analyse wurden weiterhin mit den Ergebnissen der sozio-ökonomischen Evaulation kombiniert. Zusammengenommen förderten die Ergebnisse 15 Unter-Kriterien von 3 Hauptkriterien zu Tage. Dies ist ein fundamentaler Aspekt einer entscheidungstheorethischen Fruchtbarkeitsanalyse in die mit Hilfe eines GIS-Werkzeugs ökonomische und soziale Dimensionen einfließen. Für die Abfolge und einer Einschätzung der Gewichtung der Unter-Kriterien wurde ein paarweiser vergleich mittels eines AHP-Prozesses ausgearbeitet. Als Endergebnis wurde eine thematische Karte des Kathmandu-Tals erstellt. In diesem Fall kamen für die Analyse der Bodenfruchtbarkeit Parameter zum Einsatz, welche den Anspüchen der Gemüsepflanzen entsprechen. Die entscheidungstheoretische Analyse der sozialen und ökonomischen Parameter orientierte sich an den Indikatoren im Kathmandu-Tal. Die endgültigen Ergebnisse dieser Analyse zeigt, dass 90% des Anbaugebietes im Kathmandu-Tal gut für den Gemüseanbau geeignet sein können und damit etwa mehr als 70% des Bedarfs der Region decken können. Weiterhin kann das entwickelte LIS zur Analyse anderer kulturan herangezogen und auch in anderen Regionen Nepals für ein besseres Ertragsmanagement benutzt werden. Zusammenfassend lässt sich sagen, dass die Entscheidungstheorie unter der Benutzung von GIS und AHP eine probate Methode für Länder wie Nepal darstellen. Lediglich die Bereitstellung und Verfügbarkeit aktueller Daten zum Aufbau eines LIS stellt ein Problem dar. Eine Voraussetzung ist daher die Schaffung einer Plattform zur aktuellen Verfügbarkeit dieser Daten, sowohl räumlicher als auch Sachdaten. Es sollte weiterhin neben den Regierungsorganisationen verschiedene INGOs und NGOs aus diesen Bereichen eingebunden werden, um eine funktionierendes Informationens-, Daten- und auch Software-System aufzubauen.

CONTENTS

LIST OF ABBREVIATIONS

%	:	Percentage
<	:	Less than
=	:	Equals to
>	:	Greater than
°	:	Degree
°C	:	Degree Celsius
°N	:	Degree north
AEZ	:	Agro-Ecological Zones ()
AHP	:	Analytical Hierarchy Process
APP	:	Agricultural Perspective Plan
CBS	:	Central Bureau of Statistics
CDRC	:	Coefficient of Domestic Resource Cost
CEC	:	Cation Exchange Capacity
CI	:	Consistency Index
CR	:	Consistency Ratio
CRA	:	Capital Resources Accessibility
DHM	:	Department of Hydrology and Meteorology
e.g.	:	exempli gratia (for example)
ESRI	:	Environmental Systems Research Institute
et al.	:	et alia (and others)
ET	:	Evapotranspiration
etc.	:	et cetera (and so on)
FAO	:	Food and Agricultural Organisation of United Nations
FCC	:	fertility capability classification
GDP	:	Gross Domestic Product
GIS	:	Geographic Information Systems
GON	:	Government of Nepal
GPS	:	Global Positioning System
ha	:	hectare(s)
HDI	:	Human Development Index
HMG	:	His Majesty of Government of Nepal
i.e.	:	id est (that is)

ICIMOD	:	International Centre for Integrated Mountain Development
IPNM	:	Integrated plant nutrient management
ITC	:	International Institute for Aerospace Survey and Earth Science
IUC	:	World Conservation Union
K_2O	:	Available Potassium
Kg	:	Kilogram
Km	:	kilometer
km^2	:	square kilometre
KU	:	Kathmandu University
KV	:	Kathmandu Valley
KVTDC	:	Kathmandu Valley Town Development Committee
LC	:	Land Characteristic(s)
LE	:	Land Evaluation
LIS	:	Land Information System
LMU	:	Land Mapping Units
LQ	:	Land Quality(s)
LRMP	:	Land Resources Mapping Project
LSA	:	Land Suitability Analysis
LUT	:	Land Utilization Type(s)
M	:	meter
m^2	:	square meter
MCDA	:	Multi Criteria Decision Analysis on computer
MCE	:	Multi Criteria Evaluation
mm	:	millimetre
MoA	:	Ministry of Agriculture of Nepal
MoPE	:	Ministry of Population and Environment of Nepal
MPFS	:	Master Plan of Forestry Sector
N	:	Non-suitability
N%	:	Total Nitrogen
N1	:	Currently not suitable
N2	:	Permanently not suitable
NARC	:	Nepal Agriculture Research Council
NEPAP	:	Nepal Environmental Policy and Action Plan
NGO	:	Non-Governmental Organisation

NPC	:	National Planning Commission
NPK	:	Nitrogen, Phosphorus and Potassium
NRI	:	National Research Institute
NRs	:	Nepalese Rupees
NSDI	:	National Spatial Database Infrastructure
OM	:	Organic Matter
P_2O	:	Phosphorus availability
pH	:	Soil reaction
PRA	:	Participatory Rural Approach
R/C	:	Ratio of cost revenue
RI	:	Random Index
RS	:	Remote Sensing
S1	:	High Suitability
S2	:	Medium Suitability
S3	:	Low Suitability
SOTER	:	Global and National Soils and Terrain Digital Databases (SOTER)
SWOT	:	Strength, Weakness, Opportunity and Threaten
T.U.	:	Tribhuvan University
UMP	:	Urban management Plan
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
US$	:	The United States Dollar
USDA	:	United States Department Agriculture
USAID	:	United States Agency for International Development
UTM	:	Universal Transverse Mercator
VDC	:	Village Development Committee
VDD	:	Vegetable Development Division
VFS	:	Vegetable farming system
WHC	:	Water Holding Capacity
WRB	:	World Reference Base Soil Resource

1 INTRODUCTION

Agriculture is one of the world's most important activities supporting human life. From the beginning of the civilization man has used the land resources to satisfy his needs. The land resources regeneration is very slow while the population growth is very fast, leading to an unbalance. On a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population (Davidson, 1992). Lack of wise and suitable agricultural practices results the degradation of natural habitats, ecosystems and agricultural lands round the globe. Therefore concept of land suitability evaluation was evolved. Land suitability evaluation is the process of determining the fitness of a given tract of land for a defined use (Marsh. and MacAulay, 2002).Land system analysis through improved methodology of land suitability evaluation is the main aim of present research undertaken in Kathmandu Valley of Nepal.

1.1 General background

In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites. Establishing appropriate suitability factors is the construction of suitability analysis. Careful planning of the use of land resources is based on land evaluation, which is the process of assessing the suitability of land for alternative land uses (Fresco et al, 1994). Information on land resources is a key to their careful and effective evaluation.

Land comprises the physical environment, including climate, relief, soils, hydrology and vegetation which, to the extent influence potential for land use (FAO, 1976). From the beginning of the civilization human being has used land resources to satisfy their needs. So agriculture is the very first occupation of the civilized man. Now a days agriculture became one of the good profession which has given the name as commercial agriculture, precision agriculture, etc. and sustainable agriculture as being the part of it.

Rapidly increasing populations in developing countries in recent years caused to increase the demand for food and fuel (FAO, 1986) from agricultural. Fresco et al., (1994) predicted that after 2000, population increases and income growth will increase the demand for food and other agricultural products by over 3% annually. The regeneration rate of land resources is very slow. It is not able to cope up with the ever increasing population growth; hence this situation leads to the alteration in the balanced relationship. The land is either over used or under used without considering its potential and constraints. This consequence brings a set of different problems like under production, land degradation, land use conflicts, etc. Population of the planet is growing dramatically farming community has to produce more production in order to meet the growing demand of growing population. Under present situations, where the land is one of the limiting factors, apparently it is impossible to bring more area under cultivation therefore farming community should tackle this challenge through more production from available land with intensive input. It is therefore, careful evaluation of land would help mitigate production challenge.

Land evaluation has traditionally been based primarily on soil resource inventories, commonly called soil surveys. Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. Land evaluation is concerned with the assessment of land performance when used for specified purposes. Land evaluation is also part of the process of land use planning. The main objective of the land evaluation is the prediction of the inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, in order to minimize the socio-economic and environmental costs (de la Rosa 2000). Finding suitable land area for demanding agriculture crops is the need of present day farming system.

Farming systems involve a complex combination of inputs, managed by farm households but influenced by environmental, political, economic, institutional and social factors. Farming system corresponds closely with the land use planning. The main idea is the suitability assessment of different land uses for a given location. These were then subdivided into guidelines for rain feed agriculture in 1983, forestry in 1984, irrigated agriculture in 1985, and extensive grazing in 1991 (FAO 1995), however suitability assessment framework for the mountainous area with rough and undulating topography is still lacking. Nepal being one of the same areas, it is required to develop an intuitive model for suitability evaluation.

The suitability is a function of crop requirements and land characteristics. 'Suitability is a measure of how well the qualities of land unit match the requirements of a particular form of land use' (FAO 1976). In brief, “what is to grow where?” Besides the land/soil characteristics socio-economic, market and infrastructure characteristics are some other driving forces that can influence the land selection eg. environment. Therefore, land suitability analysis is an interdisciplinary approach that includes the information from different sources like ecology, soil science, crop science, meteorology, social science, economics and management. It is also equally necessary to incorporate the expert knowledge at various levels of decision making. Land suitability is the fitness of a given type of land for a defined use. The land can be considered well supportive to specific crops in either present condition or after necessary improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976, bulletin 32). The results of land suitability are a set of land suitability classes for crops grown on different land units with specified level of inputs

The FAO has also started to classify Agro-Ecological Zones (AEZ) in order to develop an overview of production potentials. it characterized tracts of land by quantified information on climate, soils and other physical factors, which are used to predict the potential productivity for various crops according to their specific environmental and management needs. Agro-ecological zones are defined, which have similar combinations of climate and soil characteristics, and similar physical potentials for agricultural production, as part of FAO procedures (FAO 1995).

Nepal is predominantly an agricultural country with over half of its gross domestic product originating in agriculture, and more than 80% of its labor force engaged in the sector. It is obvious that agriculture must play a dominant role in the country's development, mainly through the creation of employment for the expanding labor force and by increasing labor's productivity. Farm families, generally, derive a precarious living from crop and livestock productions, often of inferior quality, on smallholdings. Physiography, agroecological zonation and climatic variation provide numerous potential for agricultural expansion in the country. Vegetable is one of the sectors in Nepalese agriculture which is supposed to make best use of available land, all form of labour force round the year, lower down poverty through nutritional supplements and upgrade living standard generating income. Therefore it is recognized by the Eighth Five Year Plan of Nepal, vegetable cultivation can contribute towards meeting most of the development objectives (NPC, 1992). Vegetable production is an important component of agriculture and also an essential part of a balanced human diet. In recent years, vegetable production has also become an income generating enterprise for those farmers who are located close to markets and road sides (Budathoki, 2002). Vegetable farming is increasing in Nepal as it has more economic returns than growing other crops, especially in the areas that have easy access to market. Vegetable farming demands intensive care and balanced nutrients input.

The diverse topographic features and climatic conditions in Nepal permit the successful production of a large number of vegetables. About 250 vegetable crops are grown in Nepal, of which more than 50 are common (Pun 1987). There is extremely limited scope for the expansion of cultivated land and almost impossible to expand anymore. Haphazard cultivation without considering land capability is further deteriorating productivity. The urbanization and wrong land use and unorganized market system in recent years has resulted in degraded scenario of agricultural output. Similar problem is transforming Kathmandu valley from a vegetable surplus valley into a vegetable deficit area (Budhathiki 2002). Therefore it is very essential to make wise assessment of the land suitability evaluation for the Kathmandu valley for the cultivation so that land capacity and crop need would be matched. This help preventing land degradation and further generate maximum possible production with minimum input cost. It is further lead towards sound and sustainable cultivation practices.

Vegetable farming is popular in peri-urban areas of Nepal as it has reasonable economic returns than growing other cereal crops. Vegetables are more profitable so, farmers allocate more resources including organic manure for its cultivation especially in the areas that have easy access to market. Vegetable farming needs balanced care of land and crops so, farmers very often cultivate vegetables near the residence. In general, using more organic manure in vegetable farms means making an amount of organic manure less available for non-vegetable farms, unless alternative arrangements for producing more quantity and quality organic manure are made. There is a risk that the soil fertility of non-vegetable farms belonging to the households growing vegetables for a long period of time may have deteriorated due to low use of organic manure. It is also possible that farmers might have used some other croping mechanisms but adequate information was not available to support this argument.

1.2 Problems Statement

A number of studies proved that increasing population and enhancing urbanization processes are converting softer green spaces into impermeable hard concrete surfaces. This trend is more serious particularly in a developing country (Shi 2002). Urban extension in Kathmandu valley is as example of this kind.

Nepal lies in the Hindukush mountain range of the Asia. Mountainous regions are at serious disadvantage when compared to flatter areas because of higher input costs for agriculture activities. One of the topographically induced main threats is erosion hazards. The effects of erosion in steep sloping mountainous areas on the degradation of the environment are widely known (ICIMOD 1999, Sherestha 2000). FAO guidelines for the land evaluation had developed for all types of land but not yet for mountainous areas which is one of the setbacks for the land areas like Kathmandu valley.

Kathmandu is the capital of Nepal. Encroachment of land areas here, for off farm use is increasing in a tremendous pace since a decade. Problem is not only limited to encroachment of the agricultural land area, is also diminishing productivity and production potential due to insufficient input owing to its higher cost. Degradation of land resources further effects on the rural livelihood, which might results into migration of the rural population towards urban centers. This result in shortage of labour supplies, especially during periods of field preparation and harvesting, and contrarily increase rate of unemployment in urban areas. There has been a dramatic change in land use composition of Valley in the periods 1984-1994 and 1994-2000. During these periods, agricultural land shrank from 64% to 52%, and further to less than 42% respectively. Agricultural land has been decreasing annually by 7.4%. Meanwhile, non-agricultural land has increased from 5.6% to 14.5% to 28% in the Valley during the same periods. (KVTDC, 2002; APO, 2002).

Present production is just enough to meet a quarter of total vegetable demand of Kathmandu dwellers. This seems under production from available land resources (KFVMDB, 2007). Although there is a lot of attraction of the farmers towards seasonal vegetable cultivation however knowledge of farmers on the land capacity for sustainable output is still not updated.

Selective land area within Kathmandu valley is being converted into settlement areas in geometric ratio. Population growth rate of Kathmandu is 5.11% and two third of which is contributed by influx of immigrants. This scenario seems to exert severe pressure on available land resources offered for cultivation valley boundary. Assuming that the present trend of urbanization continues, the total urban area will reach 34.3% of the Valley by the end of 2020. As a result of urban expansion over agricultural land it is estimated to shrink from 42.2% (2000) to just 14.5% during the same period (Shrestha, 2003; HMG/IUCN, 1995).

Core of the valley with fertile transported soil is getting rampant urbanizations. Slopping hilly areas passes high erosion risk. Therefore it is necessary to identify the land capable of supporting emerging horticulture development within the valley boundary and that is supposed to be environmentally benign. And it is necessary to strictly protect agricultural land in order to reduce the adverse environmental consequences. Further trade liberalization by adjusting crop structures, choosing appropriate plants according to eco-physiological zones and enhancing agricultural production will ameliorate the pressure to some extent.

Spontaneous exploitation of land resources, as it is occurring now, will result in an impoverished soil (Ha & Pham, 2003). Each village should have selection of suitable crops for each soil type thereby increasing the effectiveness of agriculture development programs. Theoretically this will boost inhabitants' income, prevent erosion, land degradation, protect living environment and social sustainability. There have been many studies on soil and land management in hilly region of Kathmandu Valley. However, most of the research focuses on investigating and establishing the agricultural soil map; analysing the situations of land using and management in accordance with the land law and macroscopic criteria (Ho and Huynh, 2004); assessing land and analysing natural conditions for land use planning which restricted in regional scale research and initial application of FAO assessment framework (Ha and Pham, 2003). Moreover, all of the studies are independently and sporadically conducted and lack information at community level. A new research approach in land suitability evaluation is needed from farmer's perspective and influence to make decision for the cultivation of the specific type of the crops in field. For this a complete blending of the "top-down" and "bottom-up" approaches for the selection of land area is a more realistic assessment at the village level. Land suitability evaluation always done considering the principles of sustainability of land resources.

1.3 Organisation of the thesis

Chapter 1 outlines introduction and offers basic foundations to comprehend the research. The study has been carried out in the Kathmandu valley, so general description of the study area with regard to broad Nepalese scenario is presented in chapter 5.

A conceptual framework and literatures review on aspect related to land suitability analysis are organized in chapter 2. This chapter aims to evaluate methodological approaches, taking limitation and potentiality of the land use planning into consideration. Chapter also gathering information abut agronomical need of the vegetables to be studied. Linking agronomical requirement with land potential is the crux of the study.

Setting of the hypothesis and putting objective forward for the research was systematically presented in chapter 3. Research questions putting in this chapter is the basis of investigations. In chapter 4, research methods and techniques involved on research work are presented.

Result of land resource inventory will be presented. Data sources and background of the descriptive analysis is discussed in the chapter 6, where the physical, environmental, socio-economic and infrastructure attributes are reviewed with application of adopted methodologies. In this chapter key soil properties of the study area in relation with the topographic factors and land use or potential use are presented .Chapter 6.2 is dealing with Multi-criteria land suitability analysis procedure for the present study area. Generation of LIS database is present in this chapter. Role of GIS has been discussed up to the desired detail which is incorporated with AHP methods.

In sub-chapters of 6 results of the research are discussed within the existing frame work and comparison and relationship with available literature is discussed. Difficulties and challenges to implement out come of this research are also discussed. The suitability maps will show the limitation factors of suitability level for each evaluated land unit will be validated with existing references.

Discussions over multi-criteria analysis where non attribute values are incorporated into spatial pattern are mentioned in sub section of chapter 6.3. Comparative discussion over the results obtained in research is presented in chapter 7. Chapter 8 offers conclusion and recommendation to the stakeholders. This chapter also offers some of the reasonable recommendation to the farmers as well as for policy makers.

Further chapters will covers mandatory parts like References, Appendix, etc.

2 LITERATURE REVIEW

Research works relevant to the agricultural land suitability is explored. This chapter made the compilation of the works carried out by researchers in different parts of the globe. It is very important part of the research work to make comparative assessment of the related work done in following chapters. It gives logical explanation to make conclusion through the appropriate discussion over the defined theme. Excerpts of the reviewed literature relevant to the present research work have been systematically cited. Moreover this chapter aims at presenting results of various works to readers to have clear picture over research theme and understand in wider dimension.

In Nepalese perspectives, land is the important property and is potential economic resources where all the development activities are concentrated. Economy of Nepal is predominantly based on agriculture and majority of population depends on agricultural occupation. Therefore, it requires to carry long term scientific land use planning and to implement for the balanced, multi-dimensional and sustainable development of the country on the basis of physical features, composition, quantity and capability of the land (Oli, 2001).

2.1 Land resources

2.1.1 Definition

FAO (1993) defined land is an area of the earth's surface, including all elements of the physical and biological environment that influences land use. Land comprises the physical environment including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use (FAO, 1976). Indeed, land is an essential natural resource, both for the survival and prosperity of humanity, and for the maintenance of all terrestrial ecosystems. Over millennia, people have become progressively more expert in exploiting land resources for their own ends. The limits on these resources are shown up while human demands on land are very large (FAO, 1995).

Land has been defined in varieties of ways by different researchers and organisations working in the field of agriculture and land reforms. It includes the results of past and present human activities e.g., reclamation from the sea, vegetation clearance and also adverse results, like soil salinization. Purely economic and social characteristics, however, are not included in the concept of land; these form part of the economic and social context

(FAO, 1976; Dent and Young, 1981). Land is not the same everywhere; it is, self-evidently, the other focus of land-use planning. Capital, labour, management skills and technology can be moved to where they are needed, land can not be moved and different areas posses different opportunities and also different management problems. Reliable information about land resource is thus essential for the land use planning (FAO, 1993). As definition of land is concerned, soil, climate, relief and hydrology, etc are incorporated as key words. Socio-economic and demographic parameter are not taken as an integral part of the definition. Thus it could say that land refers not only to soil but also landform, climate, hydrology, vegetation and fauna, together with land improvements such as terraces and drainage works. An other definition of land adapted by land degradation is that as a delineable area of the earth's terrestrial surface, embracing all attributes of the biosphere above or below this surface, including those of the near surface climate, the soil and terrain forms, the surface hydrology including shallow lakes, rivers, marshes and swamps, the near-surface sedimentary layers and associated groundwater and geo-hydrological reserves, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.) (IDWG/LUP, 1994). However FAO (1995) for the first time, put forward the complete definition of land incorporating socio-economic aspects as well. Land resources consist of two main categories:

1. Natural land resources without any effort made through human activities
2. Land resources created including the product of human activities such as dike and plodders (Dent and Young, 1981)

At the same time basic functions performed by land to support of the human being and other terrestrial ecosystems had numerically presented as follows (FAO, 1995):

- Provision of biological habitats for plants, animals and micro-organisms and provides physical space for settlements, industry and recreation;
- A store of wealth for individuals, groups, or a community through production of food, fiber, fuel or other biotic materials for human use;
- Co-determinant in the global energy balance and the global hydrological cycle, which provides both a source and a sink for greenhouse gases;
- Storehouse of minerals and raw materials for human use with regulation of the storage and flow of surface water and groundwater and buffer, filter or modifier for chemical pollutants;

- Storage and protection of evidence from the historical or pre-historical record (fossils, evidence of past climates, archaeological remains, etc);

Concept of land is very vague and agricultural land is only a part of this pocket cultivation and agricultural production activities are act to be carried out. In this piece the cultivation and production process impact to land resources causes to change. Land and soil is two completely different concepts, but sometime it is very confused when only concerning to the agriculture activities. Land has a much broader meaning than soil and soil is indeed a part of the land and soil quality is a subset of land quality (Kavetskiy et al, 2003). Suitability fundamentally starts with soil and land use planning accepts the soil categorization for specific purpose. In the process of land suitability evaluation and land use planning, these concepts must be clearly distinguished.

Systematic vegetable production has barely been in existence for more than three decades in Nepal. In the late 1950s local Asian varieties of mustard, pumpkin and raddish were seen in and around the Kathmandu Valley. Then, with the establishment of the Vegetable Development Division (VDD) in 1972, technical activities like indigenous and exotic germplasm collection, variety testing and seed production were initiated. In the last 10 years more serious attention has been given to identifying farmer's problems, and using trials and experiments in an attempt to solve them. More recently yield performance trials, and agronomical, fertilizer and plant protection experiments for all important summer and winter vegetables; have been conducted at all horticulture farms (NARC, 1988). Research on land suitability assessment has been initiated in the name of identification of potential packet areas for the different types of crops. They have been categorized into highly potential area, medium potential area and low potential areas for specific crops. Such activities have to be done manually using set of plant parameters and climatic background. Application of GIS has later been started.

2.1.2 Land use and land tenure

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Di Gregorio and Jansen, 1998; FAO, 1997). It is a series of operations on land, carried out by man, with the intention to obtain products and/or benefits through using land resources. According to Huizing et.al. (1995) land use can lead to the positive or negative impacts on land cover because land use is the human activities of natural environment (as defined by Di Dregorio and Janse, 1998 and FAO a report).

In Nepal, land use refers to the major classification of the use of the different parcels of land in the holdings. All land operated by agricultural holdings are classified as either agricultural land or non-agricultural land. The total numbers of all agricultural holdings in the country has been increasing (CBS 2005). On the other hand, non-agricultural land are those lands which are part of the holdings comprise woodland or forest (not commercial) and all other land, unused and undeveloped but potentially productive land and all other land in the holding not elsewhere classified including the home of the holder.

In definition of land use, it establishes a direct link between land cover and the actions of human being in their environment. The concept of land use is often considered a relatively stable subject related mainly to the use to which the land, in a certain region at a certain time, is put (Jamal, 2003). Land use is the result of a continuous field of tension created between available resources and human needs and acted upon by human efforts (Vink, 1975). The types of land use considered are limited to those, which appear to be relevant under general physical, economic and social conditions prevailing in an area. These kinds of land use serve as the subject of land evaluation. They may consist of major kinds of land use or land utilization types (FAO, 1976). FAO (1993) also defined that land use is the management of land to meet human needs including rural land use, for example, agriculture, forestry, wildlife and also urban and industry land use, for example, city, towns, industrial zones, etc. Land use and land management practices have a major impact on natural resources including water, soil, fertility, plants and animals.

The land is owned by an individual, is said to be "hold" the land. Land tenure refers to arrangements or rights under which the holder holds or uses land for particular purpose. A holding may be operated under one or more tenure forms, with each parcel normally operated under one tenure form (FAO, 1995). Many land tenure systems allow people to use the same property for different purposes. In Nepal, land tenure refers to arrangements or rights under which the holders holds or uses the land of the holding. Land owned but rented out to other is not considered as part of the holding. In Nepal, while the average holding size is small, most of the holdings are owned. The ownership of the holdings under one form of tenure is estimated to be 2,939.6 thousand ha in 2001/02 (CBS 2006).

Leasing and renting are kinds of land tenure which is very essential for farmers. Land tenure security exits when an individual perceives that she or he rights to a piece of land on a continuous basis, free from imposition or interference from outside sources, as well as the ability to reap the benefits of labour and capital invested in the land, whether in use or upon transfer to another holders.

Nepalese agricultural economy still suffers from various infrastructural, institutional, technological and agro-climatic constraints. The land tenure system is of rural type like shared cropping which could not enhance the expected productivity. The overall national policy environment may require further improvement to satisfy the needs of sustainable agricultural development rational tenure systems. The land tenure system has resulted in substantial improvements in land use efficiency and agricultural output growth.

The terms of the major kind of land use and land use type are frequently mentioned in the farming system, land suitability evaluation and land use planning, very much. A major kind of land use is a major subdivision of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forestry, etc. Major kinds of land use are usually considered in land evaluation studies of a qualitative or reconnaissance nature (FAO, 1976).

In land use classification the land utilization types (LUT) are not a categorical level but refer to any defined use below the level of the major kind of land use. It consists of a set of technical specifications in a given physical, economic and social setting for specific plant or crop patterns. This may be the current environment or a future betting modified by major land improvement, e.g. an irrigation and drainage scheme (FAO, 1976). A LUT is a kind of land use described or defined in a degree of detail greater than that of a major kind of land use (FAO, 1976). In detailed or quantitative land suitability evaluation studies, the kinds of land use considered will usually consist of land utilization types. They are described with as much detail and precision as the purpose requires. LUT has categorically presented by FAO for land with specific facilities of input. In the context of irrigated agriculture, a land utilization type refers to a crop, crop combination or cropping system with specified irrigation and management methods in a defined technical and socio-economic setting. In the context of rainfed agriculture, a land utilization type refers to a crop, crop combination or cropping system with a specified technical and socio-economic setting. A forest land utilization type consists of technical specifications in a given physical, economic and social setting. Attributes of land utilization types in general include data or assumptions on (FAO, 1976) as:

- Produce, including goods (e.g., crops, livestock timber), services (e.g., recreational facilities) or other benefits (e.g., wildlife conservation);
- Market orientation, including whether towards subsistence or commercial production;
- Capital intensity;
- Labour intensity;
- Power sources;
- Technical knowledge and attitudes of land users;
- Technology employed;
- Infrastructure requirements;
- Size and configuration of land holdings;
- Land tenure, the legal or customary manner in which rights to land are held, by individuals or groups;
- Income levels, expressed per capita, per unit of production or per unit area;

However during the land suitability evaluation process, not of all attributes above are equally concerned, the selection of attributes and detailed description level depends on current land use conditions of region as well as limitations, requirements and goals of different land evaluation projects.

2.1.3 Farming systems for vegetables (VFS)

Farming systems involve a complex combination of inputs, managed by farm households but influenced by environmental, political, economic, institutional and social factors (NRI, 2002). The functioning of any individual farm system is strongly influenced by the external environment, including policies & institutions, markets and information linkages, etc. (FAO, 2000). Whereas, a farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods, constraints, and for which similar development strategies and interventions would be appropriate. The population of individual farm systems means that they may include the major kind of land use and land utilization type or specific crops and animals. Farming system relates the whole farm rather than individual elements, contrary to this; land utilization type pays attention to the specific elements in farming system. Farming system is a complicated interwoven mesh of soil, plants, animals, implements, workers, other inputs, and environmental influences held together and manipulated by the farmers. There are several types of farming system as introduced by Kavetskiy et.al. (2003) as

a. Intensive farming system
b. Extensive farming system
c. Traditional farming system
d. Conventional farming system
e. Integrated farming system
f. Organic farming system

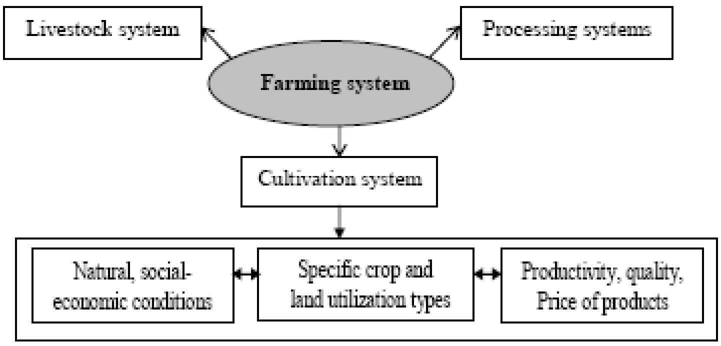


Figure: 2.1 Relationship of Farming system

If vegetable farming is ecologically sound, economically viable, socially just, culturally appropriate, long-term production, humane and based on a holistic scientific approach, it is considered as sustainable vegetable farming (FAO, 2004). Sustainable vegetable farming system is associated with good practices related to people cantered development, sustainable livelihood, sound agro-ecological practices, sustainable forestry system, community based natural resources management, participatory policy development, indigenous farming system, fair labour condition, good agricultural practises, equitable access to water and others.

Vegetable production systems in Nepal vary in land form, farm size and intention of cultivation. The production processes includes preparing seed for sowing, growing transplant, transplanting, direct seeding, land preparation, field management practice, cropping pattern and water management. The vegetable production in upland areas, declines faster compared to the decreasing size of the cultivation areas. This is mainly due to (1) decrease of quality seeds, (2) cultivation area expanded into the forest, (3) top soil erosion decreasing land fertility and (4) land degradation caused by non-conservation agriculture system, which adopt cultivation by land structure not by contour (Saptana, 2004).

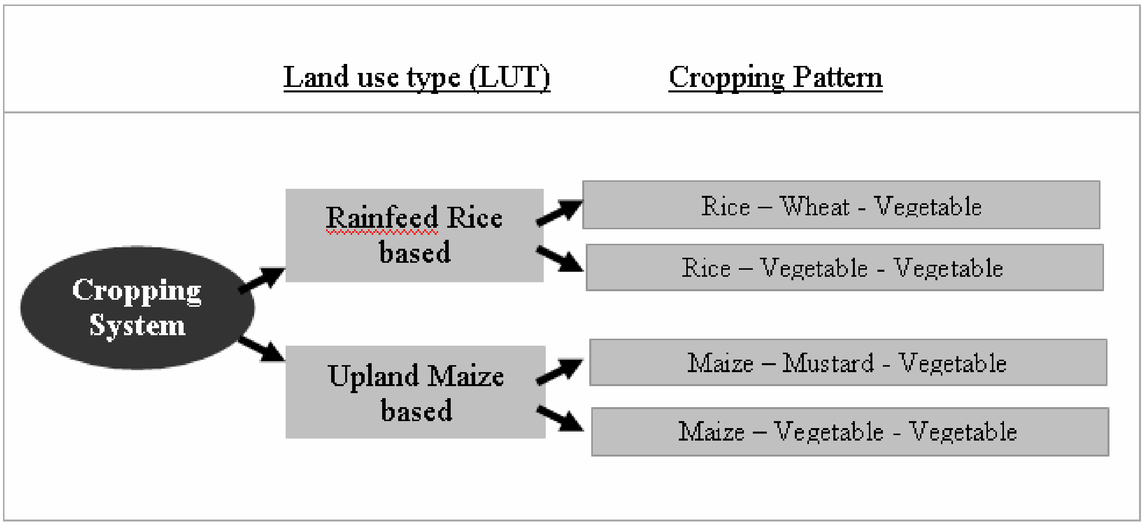


Figure: 2.2 Land utilization type and vegetable cropping system in Kathmandu

2.1.4 Vegetable production in hilly areas in the subtropics

From the competitiveness point of view, most of the vegetable farming system (VFS) activities have competitive and comparative advantages. The farming system of potatoes and tomatoes has the highest competitiveness providing the application of multi culture cropping pattern. However, the category with no competitiveness is VFS of headed cabbages in Indonesia. This is explained by: (1) low market values of land for the cultivation, resulted from price and policy distortion, depresses further the rental rate, (2) extensive usage of chemical input, much higher than the recommended one, (3) high cost per unit; (4) low productivity level and (5) limited farmers' accessibility to the market prices (Arsanti, 2008). Arsanti (2008) further conclude that the development of the VFS will be optimized, and highly profitable with a competitive competence in all aspects especially in financial, economic and sustainability providing the cultivation of potatoes by using multi culture cropping pattern as the first priority and monoculture with the different crop along year or fallow as a second priority.

Sub-tropics and Asian region has still not much developed method of farming system involving multiple sources. In order to sustain the VFS in these regions, it might have many difficulties facing regarding the natural conditions, socio-economic conditions, infrastructure and the markets. Case studies from Vietnam, Nepal, Thailand and Malaysia (Jansen et al.,

1995) clearly establish the private profitability of peri-urban vegetable production but are less specific about its communal benefits. On an average financial returns were greater than for cereal production but also much more variable (FAO, 2004).

Among the horticultural sub-sectors, vegetable production increased at the fastest rate, especially during the last decade. Although the growth in the vegetable sector in developing countries was high, almost equal to the highest growing livestock sector in these countries, expansion in this sector was exceptionally high in China, especially during 1995-2004. Production growth in horticulture in developed countries was small during the overall period, and was even negative for fruits in the later period. Most horticultural commodities are commercially produced for the market (except from home-garden), which creates substantial demand for marketing activities. In developing countries, the share of vegetable area in the farming system remained stagnant over the period. Most of the developing countries like Nepal are still adopting indigenous vegetable species which is constraints for fast expansion of the horticulture industry.

The horticultural farming as an industry is responding to environmental challenges through a number of mechanisms, including:

- Industry strategic planning;
- Adoption of management practice;
- Development and implementation of Codes of Practice;
- Research and development; and
- Interaction with State government groups.

Ecological requirements of crop

Land is always productive to specific crop with defined set of input, where selection of the crop to be planted is made considering minimum input is applied. Better the suitability of land less input is needed; where as less suitable land requires high input for production so that output cost is affected heavily. In this case suitability does not address reasonably. Input for the cropping is based on the agronomical and physiological need of specific crops. Ecological requirements of crop are the needs of an individual crop or cultivar for an appropriate development and yield. Plant growth requires a reasonable moisture and nutrient supply, linked to a sufficient rooting depth and to a proper energy regime for photosynthesis and biomass production (Verheye, 1996). FAO (1976) defined that the requirements of the land utilization type or crop refer to the set of land qualities that determine the production and management conditions of a kind of land use. Cropping system or cultivation system is the cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technology which determine their cultivation. The cropping system is subsystem of a farming system (FAO, 1996) and is illustrated as figure 2.1 and 2.2. Ecological requirements of crops are information source used for combining with the land quality and characteristic to physical land suitability evaluation.

2.1.5 Land qualities (LQ) and land characteristics (LC)

A land quality (LQ) is relevant to a given type of land use if it influences either the level of inputs required, or the magnitude of benefits obtained, or both. Land qualities may be expressed in a positive or negative way (limiting factors). Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility, etc. A Land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use (Kavetskiy et.al., 2003). There are a very large number of land qualities, but only those relevant to land use alternatives under consideration need be determined. Land qualities can sometimes be estimated or measured directly, but are frequently described by means of land characteristics. Besides the land quality, for crop growing, the soil quality also is a vital factor to be concerned. Soil is indeed a part of the land and soil quality a subset of land quality.

Soil quality examines how well a soil performs the functions of maintaining biodiversity and productivity, partitioning water and solute flow, filtering and buffering, nutrient cycling, and providing support for plants and other structures. United States Department of Agriculture (USDA) Natural Resource Conservation Service adopted the definition of soil quality is “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation”. One of the earliest definitions of soil quality made by Larson and Pierce in 1991 (cited in Kavetskiy et al, 2003), soil quality is as the state of existence of soil relative to a standard, or in terms of a degree of excellence. Later, Gregorich et.al. (1994) definite that “soil quality is a composite measure of both a soil’s ability to function and how well it functions relative to a specific use”. Management of a soil has a major impact on soil quality.

In this research, the soil characteristics are the most important factors used for physical land suitability evaluation for selected fruit crops. Soil primarily substratum where plant exist. A Land Characteristic (LC) is a simple attribute of land that can be measured or estimated in routine survey in any operational sense, including by remote sensing and census as well as by natural resource inventory. Examples are slope angle, rainfall, soil texture, available water capacity, biomass of the vegetation, etc (FAO, 1976). If land characteristics are employed directly in evaluation, problems arise from the interaction between characteristics. Besides the land characteristic, the soil characteristic is also attribute that is very important during the process of land suitability evaluation for crops. As the soil characteristics have direct influences to the growth and development of plants. Soil characteristic can be understood as a simple attribute of soil and each soil characteristic will bring about the soil quality. The glossary of soil science terms produced by the Soil Science Society of America (1996) stating soil quality is an inherent attribute of a soil that is inferred from soil characteristics or indirect observations. To proceed from a dictionary definition to a measure of soil quality, a minimum data set of soil characteristics that represents soil quality must be selected and quantified (Larson and Pierce, 1991, Gregorich et.al., 1994, Papendick et.al., 1995). A minimum data set here means that including the physical, chemical and biological characteristics of soil (Kavetskiy et al, 2003).

2.1.6 Land mapping units (LMU)

Land Mapping Unit (LMU) is an area of land demarcated on a map and possessing specified land characteristics and/or qualities (FAO, 1976). LMU is defined and mapped by natural resource surveys (e.g., soil survey, forest inventory). It is the evaluation unit about which statements will be made regarding its land suitability (Rossiter, 1996). The spatial unit of analysis for suitability evaluation is the 'land mapping unit'. The delineation of this unit should, ideally, be based on land qualities that have the most influences on the land uses under consideration. Thus, depending on the objectives of the evaluation, relevant ‘core’ data sets may include soils, landform, climate, vegetation, and surface and/or groundwater reserves. In practice, Geographic Information Systems (GIS) are commonly used to overlay relevant data sets in order to derive land mapping units (George, 2001).

A land unit must be drawn on the map delineated by polygon of specific area. It must ensure the homogeneous characteristics of the land and also have to be supported specifically by the description of attribute data. Land units must be determined by simple measures based on features that are observed directly on the field or remote sensing or others.

2.1.7 Land Sustainability

Nowadays, sustainability is one of the important issues in land use system. Sachs (1992) defined five dimensions of sustainability namely, economic, social, spatial, cultural and ecological, which should be taken into consideration while dealing with land use. It is a measure of the extent to which a form of land use is expected to meet the 'pillar' requirements of productivity, security, protection, viability and acceptability into the future. Sustainability is the ability of an agricultural system to meet evolving human needs without destroying and, if possible, by improving the natural resource base on which it depends (USAID, 1988). FAO briefly define sustainable land use as perfect balance between production and conservation (FAO, 1993) and commonly use popular definition is use of land which meets the needs of the present while at the same time conserving resources for future generations (WCED, 1987).

FAO (1976) define land suitability as the fitness of land for a specified kind of use. In general definition of sustainability indicates that there is a relationship between sustainability and suitability, stability, land degradation, and land use. This suitability of land is a function of crop requirements and soil/land characteristics and land suitability refers to use of land on a sustainable basis. It means that land suitability evaluation should take account of the hazards of soil erosion and other types of soil degradation (FAO, 1983). The sustainable land use should have maximum suitability and minimum vulnerability (de la Rosa, 2000). Land suitability is a component of sustainability evaluation of a land use.

2.1.8 Concepts of land suitability evaluation

According to FAO (1976) land evaluation (LE) is the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation. Land suitability evaluation can also be defined as the assessment or prediction of land quality for specific use. This process includes identification, selection and description of land use types relevant to the area under consideration; mapping and description of the different types of land that occur in the area and the assessment of the suitability of the different types of land for the selected land use types (FAO, 1976). Rossiter (1995) stated that the modern era of land evaluation began with the publication of the FAO "Framework for Land Evaluation" (1976) and subsequent guidelines for land evaluation of general kinds of land use (FAO, 1983; 1984; 1985; 1991).

Land suitability evaluation is the prerequisites for sustainable agricultural production. It involves evaluation of the criteria ranging from soil, terrain to socio-economic, market and infrastructure (Prakash, 2003). Land evaluation for ecological regions, territories aims at creating a new good production power together with stability and sustainability (Jamal, 2003). Land suitability evaluation requires specialists of different disciplines like soil scientists, agro-ecologists, socio-economists and planners. The evaluation relates to the environmental and socio-economic conditions of the area as it includes a consideration of inputs and projected outputs of production process.

This is the process of estimating the potential of land units for alternative kinds of use (Dent and Young, 1981). Land suitability evaluation can also be defined as the assessment or prediction of land quality for a specific use, in terms of its productivity, degradation hazards and management requirements (Austin and Basinski, 1978). Abiotic, biotic, and socio-economic factors decide the success of a crop. So the assessment regarding crop value should include the abiotic, biotic and socio-economic factors that determine the profitability (Prakash, 2003). Generally, land suitability evaluation is done for specific types of land use. Land use may be defined either at a general level (such as rainfed arable cropping) or as a particular crop at a specified level of inputs. The level of material inputs is defined in the evaluation as are land improvements such as soil conservation or drainage and their overall impact is taken into account in predicting crop yields or outputs. Recommended land uses must not cause soil erosion but must conserve the land for long-term production; improving the productivity of land use systems may involve introduction of new crops, changes in land management or other innovations in the existing farming system (FAO, 1986).

Land suitability evaluation systems

The suitability of a given piece of land is its natural ability to support a specific purpose. Suitability can be scored based on factor rating or degree of limitation of land use requirements when matched with the land qualities. In other words land suitability evaluation is a comparison and matching of land utilization type's requirements with land units' characteristics. Land suitability classes reflect degrees of suitability as shown in table 2.1.

Table: 2.1 Structure of the suitability classification (FAO, 1976)

SN	Categories	Explanation
1	Land Suitability Orders	Reflecting kinds of suitability
2	Land Suitability Classes	Reflecting degrees of suitability within Orders
3	Land Suitability Subclasses	Reflecting kinds of limitation or main kinds of improvement measures required, within Classes
4	Land Suitability Units	Reflecting minor differences in required management within Subclasses

According to the FAO general framework for land suitability evaluation (1976), the land suitability classification consists of assessing and grouping the land types in orders and classes according to their capacity. There are two orders represented by the symbols S and N. The classes (1, 2 and 3 for suitable and; 1 and 2 for unsuitable order) express the degrees of suitability or unsuitability, presented in the table 2.2. The areas that were not assessed are allocated to an extra class "NR" meaning not relevant. Land suitability orders indicate whether land is assessed as suitable or not suitable for the use under consideration. Land may be classed as not suitable for a given use for a number of reasons. It may be that the proposed use is technically impracticable, such as the irrigation of rocky steep land, or that it would cause severe environmental degradation, such as the cultivation of steep slopes.

Table 2.2 Structure of land suitability classes and subclasses (FAO, 1976)

Order	Class	Description
Suitable (S)	S1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use
	S2 (Moderately suitable)	Land having minor limitations to the given type of use
	S3 (Marginally suitable)	Land having moderate limitations to the given type of use
Non-suitable (N)	N1 (Currently not suitable)	Land having severe limitations that preclude the given type of use, but can be improved by specific management
	N2 (Permanently not suitable)	Land with so severe limitations which are very difficult to be overcome

Suitability categorization with very highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) only are being used by many researchers for different crops like *Pyrethrum* flower production in Kenya (Wandahwa and Ranst, 1996), Robusta coffee in Brazil and date palm in the Middle East. However in Nepalese contest highly preferable, medium preferable and low preferable pocket are for vegetable cultivation has been identified by panel of the expert. In this system existence of the not suitable land has strictly be omitted (MoA 2005).

Land suitability classes reflect degrees of suitability. The classes are numbered consecutively, by Arabic numbers, in sequence of decreasing degrees of suitability within the order. Within the order suitable the number of classes is not specified. There might, for example, be only two, S1 and S2. The number of classes recognized should be kept to the minimum necessary to meet interpretative aims; five should probably be the most ever used. Land suitability subclasses reflect kinds of limitations, e.g. moisture deficiency, erosion hazard. Subclasses are indicated by lower-case letters with mnemonic significance, e.g. S2m, S2e, and S3me. There are no subclasses in class S1. The number of subclasses recognized and the limitations choosen to distinguish them will differ in classifications for different purposes. The limitation factors although identified, not included in the Nepalese system of suitability evaluation. Only high, medium and low suitability classes don't reflect parameters specifically so it is a bit impractical. Limitation factors as indicated in FAO (1976) has been used by several authors like Choung (2007), Nguyen (1996), etc. Such and limitation factors are indicated by small alphabet as follows.

d : Limitations by rootable soil depth,

f : Limitations by flooding in rainy season,

g : Limitations by inappropriate soil conditions,

p : Limitations by fertility conditions,

t : Limitations by soil texture condition,

sl : Limitation by land slope of an area,

Land suitability units are subdivisions of a subclass. All the units within a subclass have the same degree of suitability at the class level and similar kinds of limitations at the subclass level. The units differ from each other in their production characteristics or in minor aspects of their management requirement. Their recognition permits detailed interpretation at the farm planning level. Suitability units are distinguished by Arabic numbers following a hyphen, e.g. S2e-1, S2e-2.

Table: 2.3 Structure of land suitability classes and sub-classes

Land suitability orders	**Land suitability classes**	**Land suitability subclasses**
S	S1 (highly suitable)	e.g. S2t° or S3sl t° = temperature, sl = soil slope
	S2 (moderately suitable)	
	S3 (marginally suitable)	
N	N1 (Currently not suitable)	
	N2 (Permanently not suitable)	

There is no limit to the number of units recognized within a subclass.

On the basis of scope of suitability two types of classifications proposed by FAO framework (1976).

1. Current suitability: refers to the suitability for a defined use of land in its present condition, without any major improvements in it.
2. Potential suitability: for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary.

Land suitability evaluation used to be done with consideration of the local need, land availability and use. There are three different methods in use to classify general land suitability for physical land conditions as described below;

1) The subjective combination method: The basis of land evaluation and classification is according to the subjective opinion of each individual. These comments will be combined and then arranged into suitable ranks. For example, if collected opinions and reference experience from people in the researched area show that there are two criteria of S2 which harmfully affects LUT, the combined land suitability (general) will be S3. Thus, if the collected opinions are of qualified and acknowledged experts with experience in natural conditions, land characteristics and socio-economic conditions of the region, this method is very good, ensuring accuracy, simplicity and rapidity.

2) Shortcoming combination method: This is the most logical and simplest method which considers the least suitable factors to be shortcomings. The general suitability level of a LMU to a LUT or plant is the lowest suitability level ever ranked of land characteristic. For instance, if there are 3 criteria of S3, S2 and S1, the general land suitability level will be S3.

***3) Parameter method**:* According to this method, land ranking can be evaluated by adding points, multiplying by percentage or grading according prescribed rank. In this method the best land is assessed as 100 points or 100% or 1, worse land is ranked in descending order like 80, 60, 40, 20 points or percentage (%), or 0.8, 0.6, 0.4, 0.2. This method of ranking is simple, easy to understand and applicable with the support of computers. During the process of ranking land suitability, it is necessary to identify dominant factors. These are decisive and irreplaceable factors, for example: types of soil, topography, depth of land layers, structures of soil and so on. Other factors can be considered as normal one which hardly affects the ranking of land suitability.

If the dominant factor has the highest limit (the most limited factor), the ranking is taken according to that level. If a normal factor has the highest limit whereas the other dominant and normal factors are at a lower limit, the rank is elevated to one more level. For instance, a normal factor is at S3 level, the other factors are at S2 and S1, then LUT will be ranked S2 (or from N to S3, or from S2 to S1). If two normal factors are at S3 and dominant factors are at S1, LUT will be ranked S2 (or from N3 to S3, or from S2 to S1). If more than 3 normal factors are at the limit, LUT will remain the rank.

Table 2.4 is the example for limits and suitability classification. When total points of all factors of land quality or characteristics is 90-100 or 0.9-1.0, the suitability class will be determined with high suitability (S1); 70-80 or 0.7-0.8, the suitability class will be medium (S2); 50-70 or 0.5-0.7, the suitability class will be low (S3); and other smallest points will be determined with non suitability (N). The selected factors of land qualities and characteristics for suitability evaluating depend on the each specific crop or land utilization types and the specific conditions of each ecological region. In addition, the methodology used for evaluating also impacts to this factor selection.

Table 2.4 Example of degrees of limitation and suitability classification (Adapted from Prakash, 2003)

	Degrees of Limitation (L) and Suitability Class				
	100	**80**	**60**	**40**	**20**
Land Characteristics	**(None)**	**(Slight)**	**(Moderate)**	**(Severe)**	**(V.Severe)**
(Paddy)					
	S1	**S2**	**S3**	**N1**	**N2**
Rainfall (mm)	>1500	1000-1500	750-1000	<750	
Slope %	0-1	1-3	3-5	5-8	>8
Drainage Class	Imperfect	Mod. well	Well drained	Excessive	Excessive
Textural Class	Sic, coarse	Sic, sc(s)	l, sl, sil (m)	Ls, fs	Sandy
(% Clay)	c(s) 40-60%				
Depth (cm)	>80	50-80	30-50	15-30	<15
NPK Rating	HHH	MMM	MML	LLL	
Organic Carbon (%)	>1.5	1-1.5	0.5-1	0.2-0.5	<0.2
Temperature (° C)	25-30	30-35	20-25	>35	<20
pH	6-7	5.5-6	7-7.5	5-5.5	<5.5,>7.5

Land evaluation is the process of predicting land performance over time according to specific types of uses (Rossiter, 1996). Land suitability evaluation is needed for various purposes in the context of present day agriculture and has to be carried out in such a way that local needs and conditions are reflected well in the final decisions (Prakash, 2003).

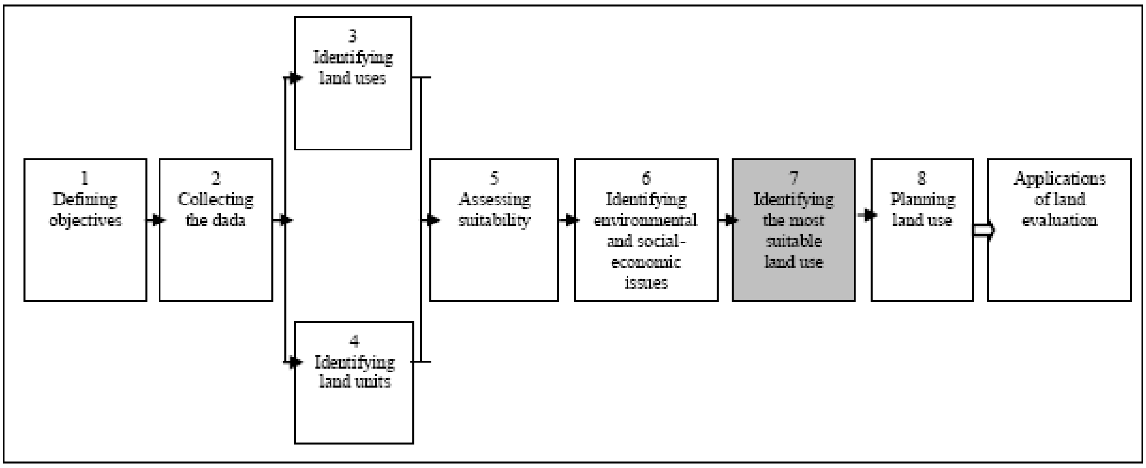


Figure 2.3 Steps of land evaluation and land use planning (FAO, 1986)

Land use planning is a tool to help policy makers, decision makers, and land users, to use land in a way (a) that current land use problems are reduced; and (b) that specified, social, economic or environmental goals (e.g., sustainability, food self-sufficiency, income, environmental conservation) are achieved (Omakupt and Huizing, 1992). Land evaluation is part of the process of land-use planning (FAO, 1986) and the results should be useful for rational land use planning (FAO, 1993). Land suitability evaluation runs as shown in the figure 2.3.

The aim of land evaluation is to determine the suitability of land for alternative, actual or potential, land uses that are relevant to the area under consideration. Land evaluation is the process of predicting the use potential of land on the basis of its attributes. Determining suitable land for a particular use is a complex process involving multiple decisions that may relate to biophysical, socio-economic and institutional/organizational aspects. A structured and consistent approach to land suitability analysis is therefore essential. The results are intended to be used for land resource related decision making, both strategic land use planning by policy/planning institutions such as extension agencies, and specific local land allocation by the direct land users, that is, the farmers (Bacic, 2003).

The evaluation of land is interdisciplinary activities that rely on large amounts of information from different sources. Finally they must present the results of the evaluation with reports and maps. This output has to be dynamic, considering the continuous refinement of the whole land evaluation process. Land evaluation is the process of predicting land performance over time according to specific types of uses (van Diepen et.al., 1991; Rossiter, 1996).

Land evaluation has traditionally been primarily based on soil resource inventories, commonly called soil surveys (Bacic 2003). These were carried out for more than a hundred years in Russia, the USA, Hungary and for at least fifty years in most other parts of the world (Boulaine, 1989; Zinck, 1995; Yaalon and Berkowicz, 1997). They were initiated mainly as support for rural land use decision making, in particular the matching of production systems (crops, varieties, rotations, fertilization and other cultural practices, conservation measures) to soil types. This support became systematized in the land capability approach (Bibby et al., 1991), where soil types were categorized by their ability to sustain general classes of land use. Starting in the 1950's, multi-purpose soil survey interpretations for non-agricultural uses became increasingly important (Bartelli, 1966). In the early 1970s, there was growing dissatisfaction with then-existing land classification systems insofar as their ability to support rational land-use planning in three main respects (Rossiter, 1994) as;

(1) Existing land classification systems were mostly or completely based on physical factors and ignored socioeconomic aspects of land use;
(2) They did not specify land uses in sufficient detail for realistic evaluation, i.e., a single classification was being applied to land uses with distinctly different requirements;
(3) They were being uncritically applied outside of their area of calibration.

These were leading to the development of land evaluation methodologies in the 1970's. According to the paper of Rossiter (1994), the FAO's Land and Water Development Division (AGL), in approximately 1973, sponsored working groups, leading to publication of the Framework for Land Evaluation in 1976. Subsequently, the FAO organized workshops leading to publication of guidelines for land evaluation (FAO, 1983; 1984; 1985; 1991; Siderius, 1986).

The participants of an international workshop for heads of national soil survey discussed the relevance of soil resource inventories was held at ITC (Holland) in 1992 and agreed on the importance of soil surveys with reservations (Zinck, 1995). Many scientists and research organizations in the world have carried out land evaluation, and the result is used in land use planning (Vo et.al. 2003), however, a lot of information is not effectively used for land use planning. The results of land evaluation from almost 15 years of working as a soil surveyor and land evaluator felt that the work was not useful to and used by the potential clients

(Bacic, 2003). Several authors have stated that decision makers do not in general make use of these land assessment results, nor are they particularly satisfied with them, if indeed they know of their existence (Rossiter, 1996; Bouma, 1997; Bouma, 1999).

The land evaluation method of FAO is adapted in many countries in the world proves to be widely feasible and significantly improved. Land statistic registration, soil map investigation, land suitability evaluation and land use planning are the main duties of land management. Together with the research achievements of edaphology, land evaluation in the past three decades has become a popular scientific field and has obtained many modern achievements. However, there are many different view points and schools in which two prominent ones are: land evaluation from the viewpoint of development and generation of Docuchaev (1983) and quantitative land evaluation (Soil Taxonomy) (Soil Survey Staff, 1962 and 1975).

At present, the FAO Framework of land suitability evaluation has been used in FAO and UNDP projects, and many national agencies, with necessary locally acceptable modifications and simplifications. The FAO Framework represented the state of the art, borrowing the best from the existing land classification methods; many weaknesses apparent on close examination and attempts to implement; "it is becoming outdated from an operational point of view, but with a function as background philosophy" (van Diepen et.al., 1991). Judgment of Rossiter on land evaluation framework of van Diepen et.al. (1991), the framework is capable of modification and interpretation, the problems have been with unimaginative applications, and the framework can be extended with new analytical techniques. The system that evaluates land in accordance with development and generation, viewpoint in Russia claimed that (Docuchaev, 1983), according to him, land evaluation should indicate the soil types and natural quality of land. These are subjective and reliable criteria. He proposed some rules in land evaluation, factors for land evaluation must be clearly and stably identified, the factors must be distinguished subjectively and scientifically, there must be research and study to improve land productivity in localities and in the whole country and finally there must be economic statistics and agricultural statistics to propose the best land use measures.

2.1.9 New trends of land suitability evaluation

Land evaluation is either of qualitative or quantitative in nature where quantitative is particularly important for economic surveys. Most land evaluation are qualitative, based on the expert judgment of soil surveyors and agronomists who interpret their field data to make understandable to planners, engineers, extension officers and farmers. More recently in-depth studies of specific soil related constraints (in particular soil fertility, available water, available oxygen, soil workability and degradation hazards such as soil erosion and soil salinization) have all facilitated quantitative simulation of specific land use processes and opened the way for yield prediction. The development of information technology during the last twenty years has enabled researchers to make rapid progress in the analysis of interactions between land resources and land use and in quantitative land evaluation based on quantitative land use systems analysis.

2.1.9.1 Qualitative to quantitative land evaluation

Quantitative economic evaluations, however, require estimates of crop yields, rates of plant growth, or other measures of performance. Quantitative models have been developed for several major crops but these demands reliable data. Such decisions need only qualitative land evaluation even when predictions are based on carefully controlled trials, they may be confounded in practice by variations in management. Therefore, it tries to estimate a range of performance under the likely standards of management (Beek et al., 2000). The Framework for land evaluation (FAO 1976) is meant particularly for use in the areas with limited availability of basic data and can function at several levels of detail. But most applications are qualitative, matching degrees of limitation of the land with the corresponding requirements of specific kinds of land use, and the overall suitability class is usually based on.

2.1.9.2 Multi-disciplinary land evaluation

Some other requirements include both the bio-physical requirements and the socio-economic setting. A choice is offered between a two-stage land evaluation procedure where the bio-physical analysis is followed by socio-economic analysis (which is preferred by most of the physical scientists) and a parallel procedure that attempts to integrate biophysical and socio-economic analyses (favoured by social scientists, especially at the farm level). Land suitability analysis and land use planning are important and being considered as a very complex question since it is usually solved by multi-criteria and interdisciplinary approaches. In general, land suitability analysis indicates the influences of physical in relation with social-economic, infrastructure, environmental issues for vegetable crops. In which social-economic and infrastructure database are used and described for maps manipulation in land evaluation and land use planning (Chuong, et al., 2006).

2.1.9.3 Land suitability assessment approaches

There are several research and studies round the globe carried out aiming on linking local and scientific knowledge like Kundiri et.al. (1997) in Nigeria, and Guillet et.al. (1996) in Peru, and Norton et.al. (1998) in New Mexico. Little work has been done in Asia and North Africa. Briggs et al (1998) studied the choice and management of cultivation sites by Bedouin in Upper Egypt. Recently Zurayk et.al. (2001) carried out a participatory land capability classification for suitability and a land use analysis in a semi-arid mountainous village in Lebanon. These efforts after all make an attempt to established relation between farmers' perception and expert knowledge. A generalised land use planning approach has to be adapted to and integrated into a prevalent political and administrative system. The issue of planning approaches has become significantly important and has been examined under seemingly opposed centralised top-down planning and participatory bottom-up planning, influenced by the increasing orientation to local needs and people that began in the 1980s (Chambers, 1994).

a) Top-down approach

When land use planning and land use evaluation carried with the decision from the state or expert or policy maker and implemented in the bottom level i.e. farming level, then it is termed as top-down approach. The classic or traditional model of top-down planning places the state as the administrator of the environment, and the state makes all decisions about resource utilisation. This makes land use planning an instrument of governmental guidance and control, closely linked to national development plans. Development potentials are assessed for all regions and goals set for all administrative levels, while monitoring is purely an assessment of goal achievement. This approach was particularly widespread in Indonesia in the National Land Agency and Sri Lanka in the Land Use Planning Division (Betke 1994).

b) Bottom-up Approach

The opposite term is bottom-up planning initiated at the local level and involves the active participation by the local community. Main decision of the land use planning will be based on the view and information raised from the level of the growers and later will incorporate in the national plan by policy makers or experts. The aim of the community at village or one level higher is the development of local planning and implementing capacities in natural resource management (Betke 1994). The experience and knowledge of land users and technical staff are mobilised to select development priorities and to formulate implementation plans. In terms of actors at the local level and responsible administrators, there are a great variety of institutions. Reference is made to now defunct Community Based Land Use Planning and Local Watershed Management Committees in Thailand within the context of the TG-HDP (Betke 1994), which shows that this idea was important, but perhaps not realistic under a contradictory policy framework.

2.2 GIS Application for land suitability evaluation

Useful suitability assessments cannot solely be based upon biophysical resource information. The other factors include transportation networks, scale dependent localized economies, and social factors such as education and demographics. Geographical Information Systems (GIS) consists of various components, starting with the incorporation of geographical data from remote sensing sources or maps and is then converted into a computer-readable form. This data can be manipulated and different data themes such as land cover and soil types can be overlaid for analytical operations. Agricultural suitability mapping involves identifying land use patterns and assessing whether the current use is the most feasible both economically and environmentally. The GIS required to service such research must incorporate high functionality and an ability to work seamlessly with both raster and vector data structures. Tabular information from census and agricultural statistics, raster image data and vectorized productivity field data all add elements to the overall study. Such data integration and equal efforts need be applied in mapping and understanding relationships evident in the compiled information. Crop modeling, including soil/water requirement and geostatistical analysis, is critical at this stage to identify and make sense of complicated spatial relationships and, ultimately, substantiate trends and theories. Progress in computing sciences, regarding this, GIS and Multi Criteria Decision Analysis on computer (MCDA) as the typical cases that can help planners handle this complexity of voluminous calculating relation to many criteria. Instead, a set of contributions concerning three areas of application of land planning has been reviewed: location choice, land suitability assessment, and collaborative decision support systems (Joerin et al., 2001). Combining GIS and MCDA is also a powerful tool to land suitability assessments. New concepts and approaches like multi-criteria method and

GIS application have developed dramatically in land evaluation, especially since 2000. This opened new directions in land evaluation so as to have appropriate crop allocation, and get higher effects when being applied to agricultural land planning. Some studies on land evaluation from new international perspectives in which the evaluation procedure of FAO is used just the initial grounds for further more detail study.

Since 1990s, GIS has been claimed as a magic tool in natural resource management as "it is ultimate in GIS the perfect answer to each and every resource problem" (Heit and Shortreid, 1991). GIS is a powerful and sophisticated tool for displaying and analyzing spatial relationships between geographic phenomena in the form of vectors and images.

With the advent of GIS, there is ample of opportunities for a more explicitly reasoned land evaluation. Geographic data as spatial data that "result from observation and measurement of earth phenomena" referenced to their locations on the earth's surface (Tomlinson, 1987). GIS is an information system including works and links together with the ability to perform numerous tasks utilizing both spatial and attribute data stored in it (ESRI, 2001). It has the ability to integrate variety of geographic technologies like Global Positioning System (GPS), and Remote Sensing (RS). The strength of GIS lies in its ability to integrate different types of data into a common spatial platform. This information should present both opportunities and constraints for the decision maker (Ghafari et al., 2000). Data from different sectors can be integrated into a single analysis without the need for each sector duplicating data collection efforts.

The powerful query, analysis and integration mechanism of GIS makes it an ideal scientific tool to analyse it for land use planning. Management of agricultural resources based on their potential and limitation is essential for development of land and other resources on sustainable basis. GIS technology is being increasingly employed by different users to create resource database and to arrive at appropriate solutions/strategies for sustainable development of agricultural resources (Venkataratnam, 2002). GIS techniques are being effectively used in recent times as tools in carrying out the morphometric analysis, which helps in suitability evaluation and management of the land resources (Obi Reddy et.al., 2002). Agriculture GIS is a tool that can assist a community to plan and to support the information management during the agricultural production process, while at the same time ensuring the proper balance between competing resource values. It can enhance the accessibility and flexibility of information and can improve the linkages and understandings of relationship between different types of information. On the average, about 80% of the resources allocated to good GIS are related to database development and management (ESRI, 1994). The spatial datasets become rather static once created. In most multi resource inventories, descriptive data are more dynamic than spatial data and as such, require more frequent updates. A good GIS design is one that incorporates a powerful database management system for efficient data storage, retrieval and manipulation of data.

There are numerous avenues where GIS can be integrated with agricultural economic studies. Changes in agricultural land use are one of the areas that agricultural economists are interested in (Shrestha, 2003). GIS is a software package or compilation of software that links a digital map with a database. Features on the map (which represent objects in the real world) are linked to records in the database, which contain a multitude of attributes and values. These components serve as a storehouse of information. The map stores physical features and the database stores information about them. A decision on the land use for crop production depends on many spatially related factors such as, microclimate, vegetation, location specific attributes such as prices of inputs, outputs, household characteristics, land holdings, land area, parcels of land holdings, land ownership and the combination of these factors with a set of production technologies that relates inputs and outputs. An active GIS market has resulted in lower costs and continual improvements in the hardware and software components of GIS. In the process of land suitability evaluation, it can be said that components of land unit, inquiries on land use for each agricultural crop are input data of this process; spatial allocation, boundary, area and scale of each suitability level for each crop are output data of land evaluation process. They are also considered as important input data to create the problem of land use (Nguyen, 2004). The land suitability classifications will be determined by overlaying thematic maps and by analysing attribute data with supporting of GIS those lead to the presentation of results faster and more exactly. The building of a GIS is a chain of operations that leads us from planning data observation and collection, to their storage and analysis, to the use of the derived information in some decision making process (Chuong 2007).

The building of a GIS is a chain of operations that leads us from planning data observation and collection, to their storage and analysis, to the use of the derived information in some decision making process. The main components of a GIS are:

Data input: Data is the most expensive GIS component. Digital data are collected from many sources such as aerial photographs, satellite images, field samples, and scanning or digitization of hard copy maps.

Data management (storage and retrieval): One of the main key elements of this work is the building of the database capable for the storage, retrieval, and sharing of the data in an easy and efficient way. The database consists of detailed information obtained during the field observation, describing the site and land facets of a particular land unit in terms of geomorphology, soil, and vegetation. The main objective of this phase is making the data ready for various types of classification for different applications mostly for land suitability evaluation. For each theme, data are selected and extracted from the data base and exported to elaboration software (spreadsheet and GIS) to produce the required output.

Spatial data manipulation and analysis: The manipulation and analysis of data determine the information that can be utilised by the GIS. Analysis is a process for looking at geographic patterns in your data and at the relationship between features; and this can be as simple as making a map or as complex as involving models that mimic the real world by combining many data layers. Manipulation involves transformation (i.e., from raster to vector data structure), generalization, overlay, and interpolation procedures.

Output: The final stage is the presentation of the result to the end users and decision makers. The results of GIS can be reported as a map, values in a table, or as a chart.

A team of expert includes physical geographers, agronomists, climate-soil-crop modelers, geostatisticians, computer programmers, economists, social scientists, and also data extension workers to ensure that the system and its products are transparent to the occasional users such as policy-makers and stakeholders at every level (FAO, 1995). Multidisciplinary natural resources teams are required to make GIS systems an effective tool in support of land evaluation and land use planning. Database is set up in form of maps and layers of information. Each map demonstrates information, spatial and non-spatial attributive relating to land evaluation objective. Sets of evaluation criteria are established in accordance with land use inquiries of each specific crop group. This step is independently conducted with employing GIS technique. Then, evaluation criteria in GIS context will be set up. Land unit map and land use inquiries for each crop types are also established and evaluation criteria are standardised to make the criterion comparable with each other. Finally, establishing land suitability map for each crop and group of crops and applying the findings to sustainable planning for agricultural land use.

Some limitations to the use of GIS technology

Application of the GIS in suitability evaluation has been use in wide range crops and land forms but still in many part of the world limitations exists as follows (FAO, 1995);

1. "The inadequate analysis of real-life problems as they occur in complex land management and sustainability issues at the household level, and as they involve the integration of biophysical, socio-economic and political considerations in a truly holistic manner;
2. The limitation in data availability and data quality at all scales, especially those that require substantial ground truthing;
3. The lack of common data exchange formats and protocol;
4. The inadequate communication means between computer systems, data suppliers and users due, for instance, to poor local telephone networks."

Some limitations that are identified to make use of GIS technology for land evaluation process in Nepal are listed as follows;

1. The local experts with insufficient training, lack of enough experiences.
2. Defective system of update and data management system and proper institutional network need to be built up a proper data management system in all fronts of research areas.
3. Networking functions among the government institutions, research agencies and academic organizations for, data collection, data exchange and updating is still lacking.
4. Lack of sufficient temporal remotely sensed and digital data coverage.
5. Level of awareness regarding GIS functionality is still rudimentary.

In recent days organisation are making good use of GIS for land related activities and gradual start in other sectors is encouraging.

2.3 Multi-criteria evaluation for land suitability

Three major phases for suitability analysis with GIS are listed as they are

a) problem formulation phase, where the situation is analysed for the problem and prospects,

b) problem understanding, generating alternatives, selecting criteria and establishing relationships among them and

c) evaluation of the alternatives using the set criteria to achieve the objective (Sharifi, 2003).

Decision making is the process that leads to a choice between a set of alternatives, and is often used in land suitability evaluation of alternatives like S1, S2, S3, and N.

The main purpose of the Multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting objectives (Voogd, 1983). Multi-criteria decision making could be understood as a world of concepts, approaches, models and methods that aid an evaluation according to several criteria (Barredo, 1996). Multi-criteria evaluation for land use issues is not a new concept, however multi-criteria evaluation based on the same principle, but implements explicitly reasoned decision rules to enable the combination of many criteria into a single index of suitability is the new concept. Multi-criteria evaluation is a transparent way of systematically collecting and processing objective information, and expressing and communicating subjective judgments concerning choice from a set of alternatives affecting several stakeholders. Such systematic, rational and transparent judgments most probably lead to more effective and efficient decisions by individuals or groups of decision makers (Sharifi et.al., 2004). The main goal of multi-criteria evaluation is to generate a gauge to compare possible alternatives or solutions. These methods integrate multiple criteria in order to combine all the relevant concerns in the decision problem as a gauge for comparison (Prakash, 2003). For continuous factors, a weighted linear combination (Voogd, 1983) is usually used. With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map.

Agricultural crop land suitability is one of the interdisciplinary approaches that involve integration of criteria from different branches of science. Criterion may be both qualitative as well as quantitative and are involved in analysing different alternatives. Decisions have to be taken at various levels starting from selecting the land utilization types or crops till the allocation of the land utilization types or crops for area that suit best. So the suitability evaluation is a multiple criteria decision making process (Prakash, 2003). Therefore, multi-criteria analysis can be used to define the most suitable areas for agricultural crops. In multi-criteria analysis technique, generation of the suitability maps for given corps is the very first step. Combining these maps to decide which crop to be best fitted for a specific location is a difficult task, so relative importance of various criteria can be well evaluated to determine the suitability by multi-criteria evaluation techniques (Ceballos and Blanco, 2003). Ceballos and Blanco (2003) conducted a study on delineation of suitable areas for crops using a multi-criteria evaluation approach and land use/cover mapping. They had shown that multi-criteria evaluation–GIS combination has potentiality to provide a rational, objective and non-biased approach on making decisions in agriculture applications. Multi-criteria decision making, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem. Fundamental components of a multi-criteria problem are human value judgment, trade-off evaluations, and assessments of the importance of criteria. Nonetheless, criteria that have GIS capabilities can be used to achieve a desired objective (Moldovanyi, 2003).

The integration of multi-criteria evaluation method with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Carver, 1991; Banai, 1993; Eastman, 1997). GIS-based multi-criteria evaluation can be thought of as a process that combines and transforms spatial and a spatial data (input) into a resultant decision (output) (Malczewski, 2004). Analytical Hierarchy Process (AHP) is a widely used method in multi-criteria decision making and was introduced by Saaty (Saaty 1977; Saaty and Vargas 2001). It is developed to select the best from a number of alternatives with respect to several criteria. AHP is a proven, effective means of dealing with complex decision making and can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria, and expediting the decision-making process. By making pair-wise comparisons at each level of the hierarchy, participants can develop relative weights, called priorities, to differentiate the importance of the criteria (Hossain et.al. 2007).

Matching of social-economic, environmental conditions and different requirements to assess the suitability is carried out by different methods. Although a variety of techniques exist comparison of weight is most accepted type. Development of weight in pairwise comparisons developed by Saaty (1977) is one of the promising decision making tool. In the past the AHP method was used for evaluation of technological processes mainly in agriculture and horticulture (Böhme, 1986). This approach enables us to compare different variants and rank the factors, criteria and parameters according to their importance. The first introduction of this technique to a GIS application was that of Rao et.al. (1991), although the procedure was developed outside the GIS software using a variety of analytical resources (Vo, et.al., 2003). The AHP is a practical and effective method for solving multi-criteria decision problems (Guo and He, 1998) which uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgment of the user (Saaty, 1980). Land suitability analysis consists of multiple criteria and alternatives which must be evaluated by a decision-maker in order to achieve a goal. The AHP provides a systematic method for comparison and weighting of these multiple criteria and alternatives by decision-makers.

Compared with other methods used for determining weights, e.g., Delphi method, the AHP method is superior because it can deal with inconsistent judgments and provides a measure of the inconsistency of the judgment of the respondents. Multi-level hierarchical structure of objectives, criteria, sub-criteria and alternatives are uses in AHP. The fundamental input to the AHP is the decision maker's answers to a series of questions of the general form, “how important is criterion A relative to criterion B, C, D, E etc” which is called pairwise comparisons. The comparisons are measured on a ratio scale. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measurements of the alternatives in terms of each individual decision criterion. Evaluation of the elements by comparison will yield preferences these preferences carries numerical values in nine point scale as described by Saaty and Vargas (1988).

The steps involved in AHP as designed by Saaty (2000) were further elaborated by (Mau-Crimmins et.al., 2003). He described the processes as objective criteria and alternatives can be many which are organize in hierarchical form. Relative importance of the criteria and preferences among the alternatives is to be made by pairwise comparisons. Then priority weight for criteria is calculated through preference. Finally the AHP process is completed by multiplying the criteria vector by the alternative matrix.

2.4 Land evaluation process in Nepal

Land evaluation on the agroecological background has begun very earlier as Dobermez (1970) made botanical exploration in the Nepal. Most of the works were carried out by Stainton (1972) on evaluation of ecosystems on the basis of climate, altitude, land soil and physiography. He identified 118 different types of ecosystems in Nepal including forest ecosystem. Most of the researches were diverted into evaluation of forestry sector because of the decreasing trend of forest cover in Nepal.

Systematic policy making processes started in Nepal in the mid 1950s with the concept of national development plans in five-year cycles. The National Planning Commission (NPC) coordinates the formulation of national development plans, as well as evaluating the annual plans of the line agencies (Subedi et.al., 2002). Inclusion of the land management policy in the plan had started quite late. Many pioneer researches were experimental and introduced solely on theoretical framework for land evaluation as introduced by FAO, but the work were putting emphasised on evaluating natural and physical conditions, land quality and fertility, where socio-economic conditions were not incorporated on the processes.

The studies carried out in the past revealed certain shortcomings, such as inflexible application of FAO procedure; merely concentrating on macroscopic projects which served big planning programs, but not directly worked with each commune where the projects were actually implemented. However, the research only employed land evaluation procedure of FAO, and evaluated natural characteristics of land affecting land use types, not focusing on socio-economic conditions and rural infrastructure during land evaluation process. The development of new viewpoints and new land evaluation approaches in the world and the occurrence of the shortcomings of the procedure have positively affected the process of land evaluation process in Nepal. New concepts and approaches like multi-criteria method and GIS application have developed gradually in land evaluation, specifically since 2000. This opened new directions in land evaluation so as to have appropriate crop allocation, and get higher effects when being applied to agricultural land planning. By calculating important indicators for three criteria economy, society and environment, the research concluded that multi-criteria analysis in land evaluation offered more positive results in selecting sustainable agricultural developing zones.

Land evaluation had apparently been started with physiographic zonation of the country. Later on this was converted into agroecological zonation. Land suitability evaluation of Kathmandu valley was started long ago but it was purely based on the soil characteristics and was done manually. Land suitability evaluation process in Nepal is gradually developing. Majority of the studies and researches are concentrating on the erodibility and erosion potential of the soil resources. Development of the model to account sedimentation and erosion is also done (Shrestha 2000) making use of the GIS and Remote Sensing technology. ICIMOD is one of the leading organisation working in the field of the land evaluation using GIS. GIS database of Kathmandu valley is one of the comprehensive publications to digitize existing land use scenario of the Kathmandu Valley (Shrestha. and Pradhan, 2000). The combination between FAO procedure and multi-criteria evaluation technique was also experimented in some areas. GIS and remote sensing technique were also employed to establish thematic map and map overlaying to create land unit map, serving land evaluation activity. Shrestha (2000) has combined slope, elevation and aspect to model erosion hazard and sedimentation proves in Nepalese mountain primarily with use of Remote Sensing images in GIS environment. He aims to evaluate land resources on the basis of its erosion hazards for the cultivation and other land use. The research in the past few years have contributed greatly to the orientation of agro-forestry developing strategies and national land use planning in term of both scientific and realistic significance.

Identification of the pocket areas by policy making institution is one of the types of the suitability classification where consideration of the land attributes and population dimensions used to be considered (MoA, 2005). Land use planning and land suitability within Nepal has been worked to some extent by OLI (2001), Thapa and Murayama (2006) and Shrestha (2000). ICIMOD and Kathmandu University (KU) had also put considerable efforts on this field.

GIS in Kathmandu valley

Recently, there is a continuing growth in use of GIS and related technologies by many researchers, professionals and organizations engaged in planning and management of the Kathmandu valley. Such studies are about an attempt to build a part of the comprehensive GIS database of the Kathmandu valley more specifically emphasized on agriculture as a means of bridging important data gaps. The study employs a fresh approach using the maps available and integrating with satellite images. The use of maps in publication visualizes prevailing status of environment and raise awareness about digital databases is in progress (ICIMOD, 1999).

It is expected that the GIS application presented in this research will expected increase awareness about the usefulness of digital databases and demonstrate benefit can be achieved with GIS and related technologies. It is also hoped that this database will improve information on the Kathmandu Valley and assist different stakeholders engaged in planning and management of services (Oli, 2001).

Furthermore, the study advocates a building block approach to development, management, and revision of databases in a complementary way to avoid duplication of efforts in costly production of digital data. The study aims to sensitize senior executives and decision-makers about the need for a sound policy on database sharing, development, and standards. Such a policy, at the national level, known as a National Spatial Database Infrastructure (NSDI), should evolve in order for everyone to benefit from the prevailing GIS technology.

3 AIM OF THE RESEARCH

This chapter deal with the hypotheses put forward to set out the research objective. To achieve the formulated objective, research questions are prepared which are based on the problem identified during the research period. Research question are guided generally by literatures and lays directions towards the development of right methodology to have expected outcome.

3.1 Hypothesis

1. Land areas of Kathmandu valley used to cultivate different races of indigenous types of vegetable crops from the very beginning. In this area it appears that vegetable cultivation practices are decreasing considerably due to some obstacles. So, first hypothesis is set as land and soil of Kathmandu valley may be selectively suitable site for vegetable crops, considerable number of selective pocket area can be identified to support vegetable farming.

2. It is expected to obtain best output on suitability analysis with collective application of participatory research appraisal as a "bottom-up" approach and land evaluation framework of FAO (1976), experts' opinion and government policies as "top-down" approach. There could be area specific modification on the suitability evaluation procedures.

3. Use of the social and economic parameter on land suitability can reflect real on farm scenario to produce promising result. This situation can effectively be handled with GIS and multi-criteria analysis. So another hypothesis can be set as application of GIS technology for databases processing, help on strengthening reliability of the result. Similarly the integration of GIS and AHP is the demanding method for the result oriented and meaningful land evaluation approach for the land area with rough topography and climatically variable area like hilly region of Nepal. Therefore, Kathmandu being one of the representative areas in this process brings real time, authentic and reliable land suitability classification map.

3.2 Objectives of the Study

The purpose of this study is to make an assessment of how is it effected by the rapid, improper and rampant growth of the urban settlements on agricultural land area of

Kathmandu Valley? The study will enumerate existing land use system, land capability and preparation of land inventory in order to produce the land suitability classification through application of AHP and GIS for the selected vegetable crops.

The specific objectives are;

1. To analyze the transformation pattern of agricultural land to non-agricultural uses in the Kathmandu Valley.
2. To develop the land information system (LIS), databases of study area.
3. To develop a land suitability model for Vegetable crop in peri-urban and rural areas of Kathmandu valley and develop model of to attain nutritional security.
4. To make analysis of the environmental, social-economic, and infrastructural conditions prevailing in the Kathmandu Valley.
5. To assess suitability integrating multi-criteria analysis and GIS making use of existing geo-database.
6. To suggest the policy guidelines that could effectively maintain sustainable balance between agriculture and non-agricultural sectors and reduce vegetable dependency out side the Valley.

3.3 Rationale of the study

Improper urban development can cause an adverse impact on agricultural land use and environmental conditions also on the livelihoods of poor inhabitants of the area. Unplanned urban growth in the valley may worsen the quality and quantity of agricultural land and its productivity in the long run. It may also have an adverse impact on agriculture-dependent disadvantaged groups in the valley. It may attract the rural poor, who will then transform into urban poor. There is a need for study on the impact of urban development on agricultural land use as well as urban poverty.

Contribution of the vegetable production from the valley land area is 23%, which could be increase to 71% with proper utilization of land and cropping pattern (Pradhan & Perara, 2005). So identification of the suitable land areas for specific vegetable seems pre-requisite. The research outcomes will expect to benefit the urban planners and policy makers and agricultural sector in the following ways:

a. Identification of the role of the government in managing agricultural land area and also plan for urban environment in the Valley.

b. The study will facilitate the conceptualization and formulation of sustainable agriculture policy to attain sustainable vegetable production and reduce adverse environmental impacts associated with cultivation

3.4 Research Questions

The soil quality of Kathmandu valley is traditionally known for the vegetable cultivation since very beginning but adoption of new and modern technology in horticultural sector is in very sluggish pace in comparison with the population out burst. Kathmandu valley is home for more and more economically active population. Being capital of the country selective migration from rural parts of the nation for employment and security is very high. Would land area of Kathmandu valley is able to meet the vegetable demand of such ever growing population? To be very efficient in vegetable production is land units produce up to their capacity? May be more important question is the cultivation in such hilly area with fragile topography ensures land use sustainability measures?

The need of very specific and detailed studies cannot be overlooked. To answer these questions related to agriculture and Kathmandu valley following research questions have been put forward to understand the matter to the reasonable depth.

Query1: How is the vegetable cultivation practices and land use condition in Kathmandu Valley?

Query 2: What are the promising vegetables in the existing land, climates, social-economic and infrastructural conditions study area?

Query 3: How does land information system (LIS) play role in suitability evaluation?

Query 4: How is physical land suitability assessment resulted?

Query 5: What are the criteria for suitability evaluation and how does multi-criteria land suitability evaluation classify land in different suitability ratings?

Query 6: Will suitability evaluation help Kathmandu valley attain vegetable self-sufficiency?

Query 7: Who are the main beneficiary of present research?

4 MATERIALS AND METHODS

The purpose of this chapter is to present fundamental materials and methods applied to obtain the required data from respective sources and a research design describes a procedural plan adopted to answer the research questions, objectively, accurately and economically (Kumar, 1996). Methodology includes the following concepts as they relate to a particular discipline or field of inquiry like a. collection of theories, concepts or ideas; b. comparative study of different approaches; and c. critique of the individual Therefore a research design provide answer for such questions as what techniques will be used to gather the data, what kind of model used to make analysis and presentation of the results.

4.1 Data sources and collection

The research focuses on the study of land suitability evaluation of vegetables in three districts namely Kathmandu, Bhaktapur and Lalitpur of Kathmandu valley. Research methods include collection of available and new field work data, data analysis using various tools and techniques. Several sources were used to gather up required data. The research needed data on climate, hydrology, topography, soil, land cover and land use. In addition to these, data were collected to assess indicators of land utilization in various altitudinal ranges. Data gathering included field surveys, laboratory analysis and secondary data collection from various organizations and individuals.

a. Attribute data sources

Majority of the attribute data were gathered from the Central Bureau of Statistics (CBS), Kathmandu. Majority of the demographic and socio-economic figures are based on the Population census 2001 and Sample Agriculture Census 2004 and Monograph of Agricultural Census 2006 has provided much more valuable data of agriculture of Nepal.

Soil inventory was based on Global and National Soils and Terrain Digital Databases (SOTER 2004) of Nepal. Soil observations were carried out using soil samples collected in the randomly sampled locations of the horticultural area. Soil descriptions were according to the FAO guidelines. Soil classifications are based on the USDA system. To study the spatial variations of selected soil properties, observations were carried out considering variations in the physiography. Existing soil fertility data were also derived through department of Soil Science, Nepal Agriculture Research Center (NARC). Data on climate and hydrology were collected from the department of hydrology and meteorology in Kathmandu. Sixteen weather stations including two agro ecological stations scattered in different locations within Kathmandu valley was used to collect climate data. More than 20 years of meteorological data were gathered and analyzed using standard methods to examine climatic variation of within the valley.

FAO Guidelines for Land Evaluation (FAO 1976, 1983, and 1993) are the basis of present research. It. would further used for analyzing agricultural structure in order to lay the foundation for collecting, evaluating and analyzing information. Further modification into Nepalese context on the basis of parameter prevails in Kathmandu valley was made according to FAO (1976) instruction. Identification of suitable land class on the basis of parameter is presented as follows;

a) Land suitability orders that reflects kinds of suitability: S (suitable) and N (Nonsuitable).
b) Land suitability classes that reflects the degrees of suitability within orders: S1 (high suitable), S2 (medium suitable), S3 (low suitable), N (non suitable).
c) Land suitability subclasses that reflect kinds of limitations required within classes, for example: m = (moisture), n = (soil nutrient), t° = (temperature), e = (erosion hazard), etc.

b. Attribute data gathering and the Inventory

Database is the building blocks of the research, so primary material required for research are data. Among those climates data gathered form department of meteorology and hydrology, information on geology of the Kathmandu valley from department of mine, data about terrain, vegetation cover, infrastructure, socio-economy is from district development committee of Kathmandu, Lalitpur and Bhaktapur districts. Similarly information about vegetable crops and production of the area gathered from NARC and District Agriculture Development Centers all the three districts of valley.

Three year plan on vegetable sector in future was collected from national planning commission (NPC). In addition, national and international institutions are also contacted for the collecting up necessary information and literatures. Ministry of Agriculture, Ministry of Forest and Soil Conservation, Ministry of Local Development are also contacted for the necessary data collection. Market related information like price and quantity available, export and import data were provided by Kalimati Fruits and Vegetable Market

Development Board (KFVMDB. Collected materials include annual reports, five-year summation reports, agricultural projects and research, statistic figures of district level, some map. National remote sensing section was contacted to collect satellite image which will logically be used to check biophysical changes in the map of study site.

c. Interview, discussion and seminar

Primary data collection accomplished by questionnaire survey which is one of the important social research methodologies. It is best used to identify problem in the study area and to setting up priority of requirement is made. Conclusion brought was derived as attribute data. Direct and indirect unstructured interview (Participatory Research Appraisal, PRA) were also done with farmers. This research makes use of well structured questionnaire to farmer households in intensive vegetable farming areas. Formal and informal interview, group discussion was also conducted to gather information.

Seminars and meetings conducted with experts, officials, and policy makers were also used to make assessment of the valley agriculture condition. All these data were tabulated in the MS Access format and further processing was done under specific heading. Seminars were used to receive feedback information and also set the assessment criteria appropriately on the basis of bio-physical condition of the locality.

d. Thematic maps

Thematic maps are the basis of the suitability analysis. The maps in present study include land use map, land capability, soil maps and map of administrative boundaries. Those thematic maps are created and edited, overlaid and visualized on ArcGIS and ArcView software of ESRI. Application of GIS for overlaying thematic layers to establish land databases, all the layer maps has to be converted into consistent coordinate system. Geometric correction has been performed for the maps of different origin were converted into Universal Transverse Mercator (UTM) projection. Topographic data were derived from map sheets from Department of Land Survey, Government of Nepal, at scales of 1:25,000 and 1:50:000 for present study. Several maps like land capability map, land use map, road map and administrative boundary maps were collected. Some map designed in GIS data base of Kathmandu had been derived through the courtesy of the Integrated Mountain Development (ICIMOD). With application of ArcGIS 9, coordinate system had been amended from UTM projection with false easting 400,000 to the Modified Universal Transverse Mercator with false easting 500,000.

Software used for data management

Software used for this study includes;

1) MS word is use to make creation of all this thesis type setting and printing.
2) MS Access and MS Excel 2003 were used to create the attribute databases and import or export to GIS environment for next implementation. Macro created on MS Excel software was used for multi-criteria analysis (weighting, rating) based on Analytical Hierarchy Process as theory put forward by Saaty (1980).
3) ArcGIS is the software use to make analysis of all the GIS work in the thematic layers of the study area map.
4) ERDAS is used just to make visualization of satellite images. Such images are used to check real time changes in the study area and make necessary amendments on the thematic layers.
5) Arc view 3.3 and MapInfo 7.5 software were used to analysis, store, query, and outputs and convert the GIS data collected from different sources.

4.2 Methods of land suitability evaluation

4.2.1 GIS application

One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis. The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitant for animal and plant species (Store and Kangas, 2001). ArcVeiw and ArcGIS from ESRI has been used as tool for the GIS analysis of present study. The map overlay approach has been typically applied to land-use suitability in the form of weighed linear combination (WLC). The primary reason for the popularity of these methods is that they are easy to implement within the GIS environment using map algebra operations. The methods are also easy-to-understand and intuitively appealing to decision makers.

Most GIS systems are database oriented. The integration of multi-criteria decision management (MCDM) techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Malczewski, 2004). GIS-based MCDA can be thought of as a process that combines and transforms spatial and non-spatial data (input) into a resultant decision (output). The MCDM procedures (or decision rules) define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker's preferences and the manipulation of the data and preferences according to specified decision rules. Accordingly, two considerations are of critical importance for spatial MCDA: (i) the GIS capabilities of data acquisition, storage, retrieval, manipulation and analysis, and (ii) the MCDM capabilities for combining the geographical data and the decision maker's preferences and non-spatial attributive data into unidimensional values of alternative decisions. A number of multi-criteria decision rules have been implemented in the GIS environment for tackling land-use suitability problems.

4.2.2 Criteria for physical suitability evaluation

Suitability analysis is the decision making part which is the vital of the suitability assessment job. Based on the vegetable cultivation parameter, selection of the suitable mode for the decision analysis is needed. The criteria are selected from physical environment, social and economic aspects including infrastructural aspect. It works as shown in the organized conceptual flow research diagram in this text (figure 4.1)

Physical land suitability evaluation is carried out with analysis of soil characteristics, land characteristic and climate characteristic. The method use for the analysis is presented as follows.

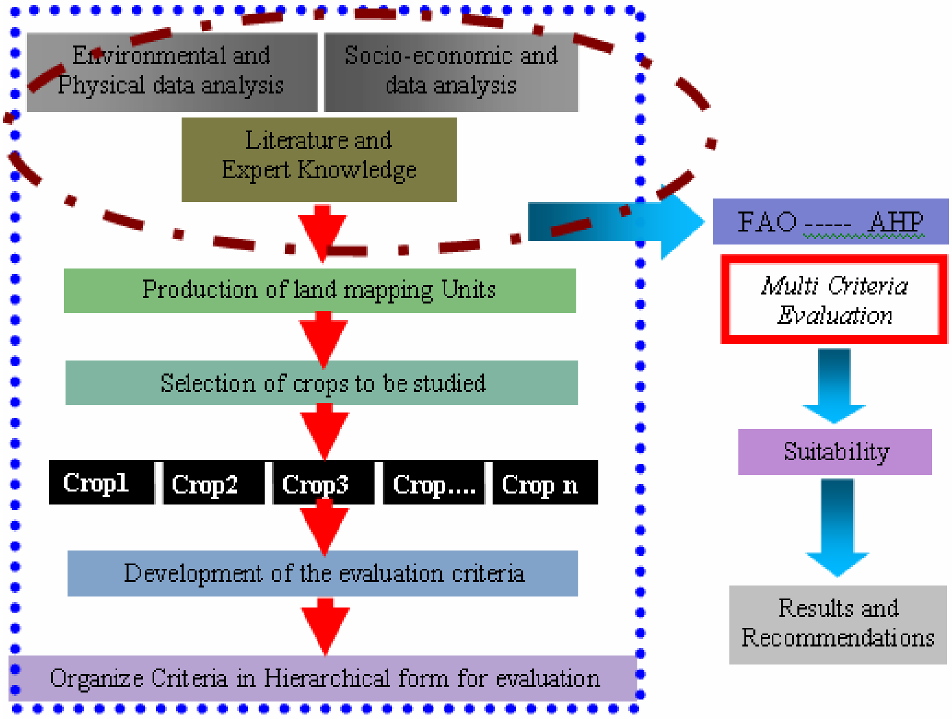


Figure: 4.1 Conceptual flow of the research approach

Soil analysis

Soil collection

A special type of soil auger was used for soil collection. When the auger was pushed and screwed in clockwise direction, soil moved upward in to the auger after driving up to required depth it was pulled out and the soil collected in side was removed. With the help of this auger soil sample was collected from upper 10cm of surface soil. Litter layer was collected from three stations, randomly located inside the quadrate considering three altitude classes, the soil samples from each quadrate were mixed together in a cellophane bag and brought in to laboratory the following day for investigation.

Analytical Methods

The collected soil samples were investigated in laboratory of Soil Science Division, Agriculture Department, HMG, Khumaltar and Central Department of Environmental sciences, T.U., Kirtipur using following methods;

Soil Texture

Texture of soil samples was done determining percentage of sand, silt and clay according to USDA system by Hydrometer method (Piper, 1942). Then texture class was determined by texture triangle.

Water Holding Capacity

A clean filter paper was placed in funnel. Ten ml of water was poured on filter paper and excess water was collected in petridish below and measured. Volume of water absorbed by filter paper was calculated. 50 gm of dry soil was placed on filter paper inside the funnel. Then water was poured carefully on it with the help of pipette. A drop of water coming out of the funnel marked the maximum water holding capacity of soil.

Soil pH

Soil reaction (pH) was measured by potentiometric method. Soil suspension was made with distilled water in 1:1 ratio. Then the pH was measured with a Coleman glass electrode pH meter.

Nitrogen

Nitrogen in the soil is present in different forms and in very small quantities. This total nitrogen was estimated by modified Kjeldahl method.

Potassium

Soil was extracted with neutral 1 N ammonia acetate. Exchangeable potassium in the soil was replaced by ammonia ion and the potassium released into solution and that was estimated by the flame photometer method.

Phosphorus

Amount of phosphorus in the soil was estimated using spectrophotometer by Bray No.2 method.

Organic Matter

Organic matter of the soil sample was determined by Grahm Colorimetric method. This procedure involves oxidation of readialy oxidizable soil organic matter by potassium dichromate solution and measuring reduced chromium ion colorimetrically (Grahm, 1948).

The selection of criteria is the crux of the suitability analysis. Physical land suitability evaluation is based on biophysical conditions of the study area. The process of selecting the main criteria and sub-criteria is iterative in nature. Literature review, analytical study and the local opinions were basic tools for selection of evaluation criteria. Based on FAO Framework for Land Evaluation mapping unit was determined physical land suitability will be assessed on the basic of soil parameter as follows.

1. Soil unit type (according to FAO soil classification system)
2. Soil texture
3. Soil effective depth
4. Soil slope degree
5. Soil fertility

Besides soil parameters, the climate factor like rainfall, temperature, humidity, wind regime, sunshine hours, drought, flood, and erosion are also taken into consideration. Area like Kathmandu valley where topography, slope, aspect, etc develop considerable difference in the micro-climatic regime within study area the land unit can carefully be delineated. However, in the area of topographic homogeneity, these factors are supposed to be consistent and not showed in land unit. To physical land suitability evaluation, the detailed flowchart of physical land suitability evaluation is showed in the Figure 4.2.

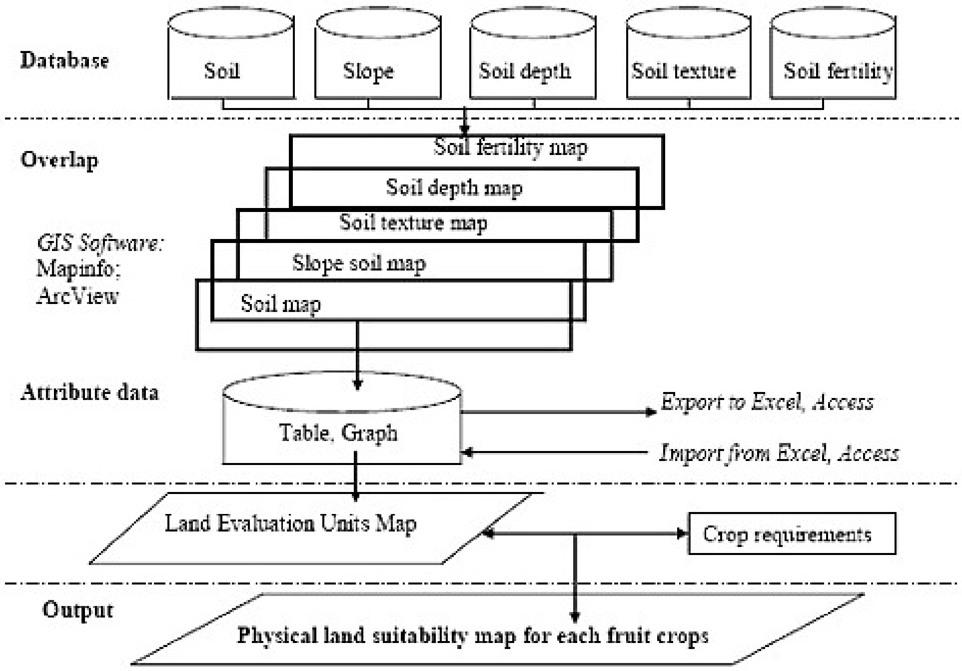


Figure: 4.2 Chart of GIS application to physical land suitability evaluation (Inherited from Chuong, 2007)

4.2.3 Selection of promising vegetable crops

In determining the vegetable having high priority for the cultivation in the study area, the product should focus on an array of aspects. For examples, profitability or the ratio of revenue cost (R/C), and the sustainability factors, including the physical and agro-ecological adjustment are considered. Similarly availability and type of input, local culture and habit, demography, potential local market, institution and government and accessibility are also taken into account.

The aim of this step is to select promising vegetable crop for study area within given set of physical and socio-economical condition. Since vegetable are short term crops requiring intensive attention and input, they are grouped for the purpose of study. On the basis of existing cropping systems, social acceptance of vegetable crops, agricultural know-how of vegetable growers, major agricultural markets, facilities availability, population and economic status of the society and from the experience of long period of growing by farmers it is decided which crops are promising in given locality. Vegetable constitutes major portion of daily diet of local people hence consumption rate is also another parameter for vegetable selection. Besides those, local food habit, nutritional requirements etc were also look upon to make decision. Prevalence of the under weight due to the malnutrition in Kathmandu valley is still 19% (CBS, WFP and World Bank, 2006). Cauliflower, potato and carrots could be major supplement to the nutritional deficiency occurrence in many parts of country. Kathmandu valley once used to vegetable exporting valley is getting completely dependent on outside for more then 72% of its need (Pradhan & Perara, 2005). It is highly aimed that if production of selected vegetable is done identifying suitable area, that will help reduce half the total demand of vegetable in study area. From the Kalimati market data, it appeared that little about half of imported vegetable in the valley makes up with potato, tomato, cauliflower and cabbage (KFVMDB 2007). Selected vegetables are those which used to be exported from the valley to outer district of the country. Basis of selection has been presented in bullet as follows;

- Very high consumption.
- Help reduce vegetable demand and decrease dependency to outside valley.
- Contribution to family income considerably.
- Availability of local demanding varieties as well as improved varieties.
- As a potential nutritional supplements and help reduce poverty.
- Climatic favourability.
- Popularity on vegetable cultivation.

Table: 4.1 Groups of vegetable to be evaluated for land suitability

Crops Group	Representative species	Nepali Name	Family
Cole crops	Cabbage & Cauliflower	Kauli	Brasicaceae
Root and tuber crops	Potato, Radish & Carrot	Aalu Mula, gasar	Solanaceae/ Apiceae
Fruit and leaves crops	Tomato	Golvenda	Solanaceae

Priority rating of the willingness of the vegetable growers in rural area of Kathmandu valley was also assessed during field visit. Participatory Research Appraisal (PRA) with growers also forms the basis for selection of given vegetable groups. Therefore, with consideration and peer review of background and consultation with horticulturist, promising vegetable for study in case of Kathmandu has been selected. Table 4.1 shows vegetable groups with high rate of consumption are considered for the suitability assessment.

Land, soil and climatic parameter of given area has variability in certain range. Fluctuation of this range could cause change in growth and development of vegetable crops effecting is final yield. Such parameters, therefore catagorised in potential ranges according to need of the crops as shown in the table: 4.2, 4.3 and 4.4 for cole crops, tomato and root and tuber crops respectively.

Table: 4.2 Diagnostic characteristics for Cole Crops (Cabbage, Cauliflower, Broccoli),

Parameters	Potential Ratings			
	High	Moderate	Low	Very Low
Temperature	18 - 27	15-18, 28 -35	10 -15	<10 & > 27
Soil Texture	Loam	Silty Loam, Clay Loam	Silty Clay,	Bouldery, clay
Fertility	High	Moderate	Low	Very low
Aspect (in hills only)	South East	North East	South	West-North
Soil pH	5.5 – 6.5	6.5 -7.5	> 7.5	<4.4
Irrigation	Regular	Partial	Rainfed	devoid
Input	Readily Available	Available	Not available	Not available
Services (km)	< 5	5 -10	10 - 15	> 15
Soil depth	> 100cm	55 – 100cm	30 – 55 cm	< 55
Slope(degree)	Flat to 1	1 – 5	3 - 8	steep

References, Ministry of Agriculture and Agronomy of vegetables crops, 2004

Table: 4.3 Diagnostic characteristics for suitability of Tomato

Parameters	Potential Ratings			
	High	Moderate	Low	Very Low
Temperature	18 - 27	15-18, 28 -35	10 -15	< 15 & >35
Soil Texture	Loamy sand	Sandy Loam	Clay, sand	Bouldery
Fertility	High	Moderate	Low	Very low
Organic matter content (%)	> 3	3 - 2	2 - 1	<1
Soil pH	5.0 -6.5	6.5 -7.5	< 5.0 and > 7.5	
Irrigation	Regular	Readily available	Rained	Not available
Input	Readily Available	Available	Not available	
Soil depth (cm)	> 100cm	55 – 100cm	30 – 55 cm	< 30
Slope (degree)	Flat to 1	1 – 5	3 - 8	steep

References, Ministry of Agriculture and Agronomy of vegetables crops, 2004

Table: 4.4 Diagnostic characteristics for suitability Root crops (Radish and Turnip, carrot)

Parameters	Potential Ratings			
	High	Moderate	Low	Very Low
Soil Texture	Sandy Loam, Loam	Silt loam	Clay loam	Gravel
Temperature (0C)	> 10 - < 15	15 – 20	> 20	
Fertility	High	Moderate	Low	Very low
Soil pH	< 5.5 -6.0	>6.0 - 6.5	< 5.0 & > 6.5	
Irrigation	Regular	Partly available	Rain feed	Not available
Access of Road (km)	Near < 2	2	>2	
Access to collection center (km)	5	15	>15	
Soil depth (cm)	> 100	80 – 100	55 - 80	< 55
Slope (degree)	Flat to 1	1 – 8	3 - 15	steep
Aspects (direction)	South East	North east	South	
Pocket area (ha)	=>20	10	<10	

References, Ministry of Agriculture and Agronomy of vegetables crops, 2004

The methodology is based on matching soil/land characteristics against agronomical requirements of crop and then the suitability classification will be assessed. The physical land suitability evaluation used limiting factors method assigning the suitability classes, in which the lowest suitability class will limit for the rest of factor. Therefore, the overall suitability class will be the lowest suitability class.

4.3 Social-economic and environmental suitability evaluation

Social and cultural characteristics influence cultivation pattern land evaluation in developing countries like Nepal is also effected by social attributes. Importance of social parameter for suitability classification should be raised from the opinion of individual and corresponding weight can be given for analysis purpose. These parameters are then classified into certain and sub criteria for evaluation purpose. The weight and rates of each criterion and sub-criteria, the multiplication process and reclassification for different suitability classes use AHP for comparisons (Saaty, 1977). The flowchart of social, economic and environmental land suitability analysis is presented as follows (figure 4.3).

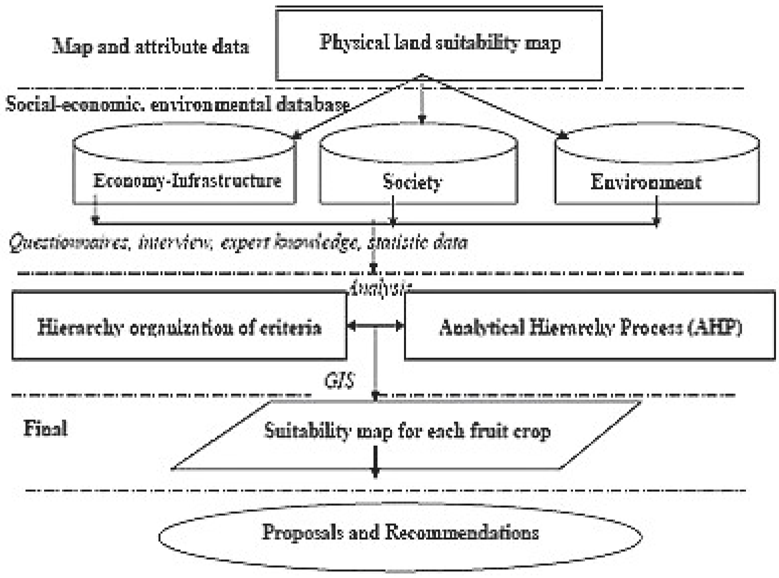


Figure 4.3 flow chart showing application of GIS and AHP for physical environment, social and economic-infrastructure suitability evaluation.

Socio-economic, environmental suitability evaluation is carried only on those areas which are physically suitable. If land unit show degree of unsuitability in physical suitability assessment, they are further not taken for the suitability assessment. So, non-suitable land areas (N) are not considered for suitability evaluation step.

Hierarchical organization of criteria

The selection of the main criteria and sub-criteria for each of the Social-economic and environmental evaluation is the first step as done in physical suitability evaluation process. This is much interactive in nature. Literature reviewing, analytical studying and the expert opinions gathering were tools that aided in the selection of evaluation criteria. Based on the output of the research there are three main criteria groups are considered including economy-infrastructure, society, and environment. These are further fragmented into number of sub-criteria. The detail of the selection and development of the criteria and sub-criteria is represented in lay out below (Figure 4.4). Hierarchical organization of the criteria and sub-criteria was required which was based on opinions and ideas of farmers, expert knowledge, and key groups. In hierarchical structure, main criteria forms highest hierarchical position where as, the sub-criteria are decomposed at lower levels.

Weightings of criteria and sub-criteria

In the procedure for multi-criteria evaluation using a weighting and comparisons of criteria involved to determine suitability for the stated objective. Ratings are provided on a 1 point continuous scale.

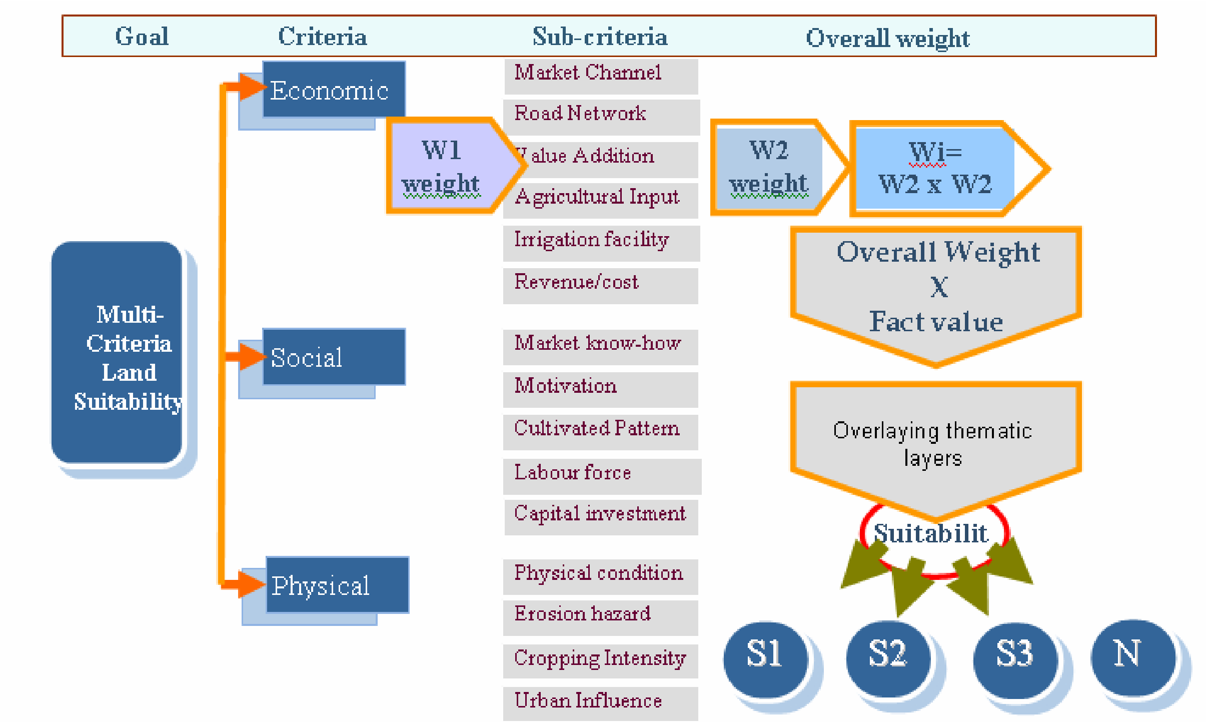


Figure: 4.4 flow chart of the suitability analysis methodology

4.4 Analytical hierarchy process (AHP)

Analytic Hierarchy Process is a widely used method in decision-making. AHP is introduced by Saaty (1977), with the basic assumption that comparison of two elements is derived from their real- time importance. AHP technique is the crux of this assessment, because careful organisation of sub-criteria of main criteria if weights properly, represent perfect suitability order and fulfills the goal. After all AHP is the weighting and comparing procedure.

The AHP is based on three principles:

a. Decomposition of the overall goal (suitability),

b. Comparative judgment of the criteria, and

c. Synthesis of the priorities.

The first step of AHP technique begins with the structuring of the criteria and sub-criteria required for the land suitability and set them in a hierarchical form. The overall goal of the research is suitability evaluation which occupies the top most level in the hierarchy. The next level consists of the main criteria set out to support the goal, and sub-criteria of the criteria occupy position in the next hierarchical level. At the bottom level there are the alternatives to be evaluated. Applying this step to land suitability evaluation, decision criteria relevant to the goal were identified and arranged in the hierarchy illustrated in figure above. Such structure allows the incorporation and accommodation of both qualitative and quantitative criteria for assessing land suitability. GIS have emerged as useful computer-based tools for spatial description and manipulation.

Table: 4.5 Fundamental Scale used in Pairwise Comparison (Saaty and Vargas 2001)

Qualitative Definition	Explanation	Intensity of Importance
Equal importance	Two activities contribute equally to the objective	1
Weak		2
Moderate importance	Experience and judgments slightly favour one activity over another	3
Moderate plus		4
Strong importance	Experience and judgment strongly favour one activity over another	5
Strong plus		6
Very strong or demonstrated importance	An activity is favored very strongly over another and dominance is demonstrated in practice	7
Very, very strong		8
Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation	9

Hierarchical organization is followed by is the comparison between the alternatives, criteria and sub-criteria. They are compared in pairs with respect to each factor of the next higher level. For this relative comparison, the fundamental scale of table 4.5 can be used. It allows expressing the comparisons in verbal terms which are then translated in the corresponding numbers. When the factor on the vertical axis is more important than the factor on the horizontal axis, this value varies between 1 and 9. Conversely, the value varies between the reciprocals 1/2 and 1/9 (see table 4.6).

For example, if comparing criteria A to criteria B, a score of 1 indicates that they are equally relevant to the evaluation of suitability and a score of 9 indicates that B is of little significance relative to A. All scores can be assembled in a pair-wise comparison matrix with 1s on the diagonal (e.g., A to A is 1) and reciprocal scores in the lower left triangle (e.g., if A to B is 5, then B to A is 1/5).

Table 4.6 An example of pair wise comparison matrix of criteria in AHP

Goal	A	B	C	D	E	F	Weights	Ranking
A	1	2	7	3	5	3	0.365	1
B	1/2	1	6	3	5	2	0.264	2
C	1/7	1/6	1	1/2	1/4	1/2	0.064	6
D	1/3	1/3	4	1	4	1	0.127	3
E	1/5	1/5	2	1/4	1	1/3	0.073	5
F	1/3	1/2	4	1	3	1	0.125	4
λmax = 6.428	**CI =0.086**			**CR = 0.069**			**Σ=1**	

AHP finally set out the priorities of the alternatives and the weights of each criterion with respect to the goal. The local priorities are then multiplied by the weights of the respective criterion. The results are summed up to get the overall priority of each alternative. For each level in the hierarchy it is necessary to know whether the pair-wise comparison has been consistent in order to accept the results of the weighting. The Consistency Ratio (CR) is a measure of how much variation is allowed for reasonable results that is expected to be less than 10 percent for the reasonable result. CR calculation is described as in following formula from the matrix Goal calculation, λmax value can be gained and later it is used to count Consistency Ratio (CR) and Wi which becomes the priority vector. The formula of Consistency Ratio (CR) got from the Consistency Index (CI) is as follows:

$CI = (\lambda max - n) / (n - 1)$

$CR = CI / RI$

Where: λmax: The maximum eigen value

CI : Consistency Index

CR : Consistency Ratio

RI : Random Index

n: The numbers of criteria or sub-criteria in each pairwise comparison matrix

Random Index (RI) says that the average of consistency of comparative matrix in pairs is 1-10, got from the experiment of *Oak Ridge National Laboratory* and *Wharton School*. The bigger the matrix is, the higher the inconsistency level will be (Permadi, 1992). Matrix Random Index can be seen in table below.

Table 4.7 Average Random Consistency Index (RI) (Permadi, 1992)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1.32	1,41	1,45	1,49

The requirements needed are:

If CR ≤ 10%, means matrix is consistent and AHP can be continued.

If CR > 10%, assessment require revision because matrix is not consistent.

If CR in level 1 meets the requirement, the next step is making pairwise comparison matrix for level 2 for each sub criterion applied. In every matrix, λmax, CI, and CR are also counted by using the same formula and requirement. Applying the above following steps, the final weights for criteria and sub-criteria are shown in chapter 7. The fact value (X) of evaluated criteria and suitability index (S) of land unit for vegetable crops in the study area are presented in the table below. Value or score (Xi) of each level 2 of criterion is computed for each land unit. Scores for the socio-economic, physical environment criteria are calculated based on expert knowledge and farmer opinions. Local conditions assessment and outcome of the questionnaire, seminar and discussion were also made use for this. These fact values (Xi) are combined with the above weightings (Wi) to provide suitability value for each land unit corresponding to each selected fruit crop.

Table: 4.8 Fact value classifications for each criterion for each LMU

	Sub-criteria	Attribute values of criteria	Score (xi)
Criteria 1 : Infrastructural Parameters			
	Irrigation facilities availability	Perennial irrigation sources	9
		Seasonal irrigation availability	7
		No irrigation except rein fed	5
	Road Network and condition	Good condition motorable road	9
		Far from road head	7
		Far and bad road condition	5
	Value addition process	Available processing know-how	9
		Lack of processing facilities	7
	Market channel	Good institutionalized regular market	9
		Lack of proper market system to sell product	7
	Agricultural input availability	Available all the time	9
		Seasonal unavailability	7
		Unavailable	5
	Revenue Cost ratio	Above 1.2	9
		Below 1.2	7
Criteria 2 : Social Parameters			
	Marketing know how	Good market accessibility and marketing information	9
		Lack of marketing information	7
		Inaccessible markets	5
	Motivation of Farmers	Motivated and trained	9
		Trained	7
		Unskilled	5
	Cultivation Pattern	Market oriented	9
		Household consumption	7
		Utilization of farmland only	5
	Labour force	Easy and round the year available	9
		Easy and seasonal availability	7
		Scarce labour force	5
		Scarce and expensive	3

	Investment capacity	Minor capitol resource needed	9
		High capitol requirement	7
		Very high capital resource requirement	6
Criteria 3 : Physical Parameters			
	Physical condition	Highly suitable (S1)	9
		Medium suitability (S2)	7
		Low suitability (S3)	5
	Erosion Potential	Stable	9
		Susceptible to Erosion	7
		Highly Vulnerable to erosion	5
	Crop Intensity	Intensive	9
		Moderate	7
		Extensive	5
	Risk of urban sprawl	Low	9
		High	5

The formula for calculating the suitability index of each layer as follow:

$$\mathbf{Si = \Sigma Xi \ x \ Wi}$$

Where

Wi is weighting of the each criterion, as presented in AHP techniques above.

Xi is fact value of each criterion, an example of Xi is showed in Table 4.8.

Si: is suitability index.

The score of the criteria obtained from the AHP will be stored as attribute data of each of the land unit of study area. ArcGIS is used to combine spatial data with suitability index so that a continuous land suitability map is generated.

Once the weight value assigned for each class of each map, all of maps of factors for each land use type will be multiplied together. This study conducted calculations of the weight and fact value of each criteria and sub-criteria, produced the theme layers of each sub-criteria, overlaid all the theme layers for having the final suitability classification. The thematic map with suitability value will be generated for each of the criteria and sub criteria. They are overlaid accordingly for final suitability classification within study area.

Standardization of the criteria maps

The process of setting the relative importance of the classes of criteria is called standardization. Criteria standardization is done in present study on scale of 1-9 (table 4.9).

Table: 4.9 Suitability classifications with numerical value

Si (point)	**Suitability classification**	**Explanation**
8-9	High suitable (S1)	Suitable capacity of locations is high and satisfies all criteria set up.
7-8	Medium suitable (S2)	Suitable capacity of locations is medium and satisfies most of the criteria set up, but some criteria are not satisfied.
<7	Low suitable (S3)	Suitable capacity of locations is low and satisfies some of the criteria set up, but most of the criteria are not satisfied.

After weightings and rating of all criteria over the hierarchy obtained, standardized criteria maps are multiplied (**Si = ΣXi x Wi**) with these criteria weights at each level of the hierarchy as shown in Figure 4.5. In land suitability analysis, a map represents each evaluation criterion with alternatives (like S1, S2, S3, and N) indicating the degree of suitability with respect to a criterion. These classes have to be rated, how important is the class S1 with respect to a particular criteria to contribute for the final goal (suitability). In this particular land suitability analysis the criteria are mainly related to economy-infrastructure, society, and environment. Some sub-criteria of them can be represented by the GIS layer and some are purely non spatial.

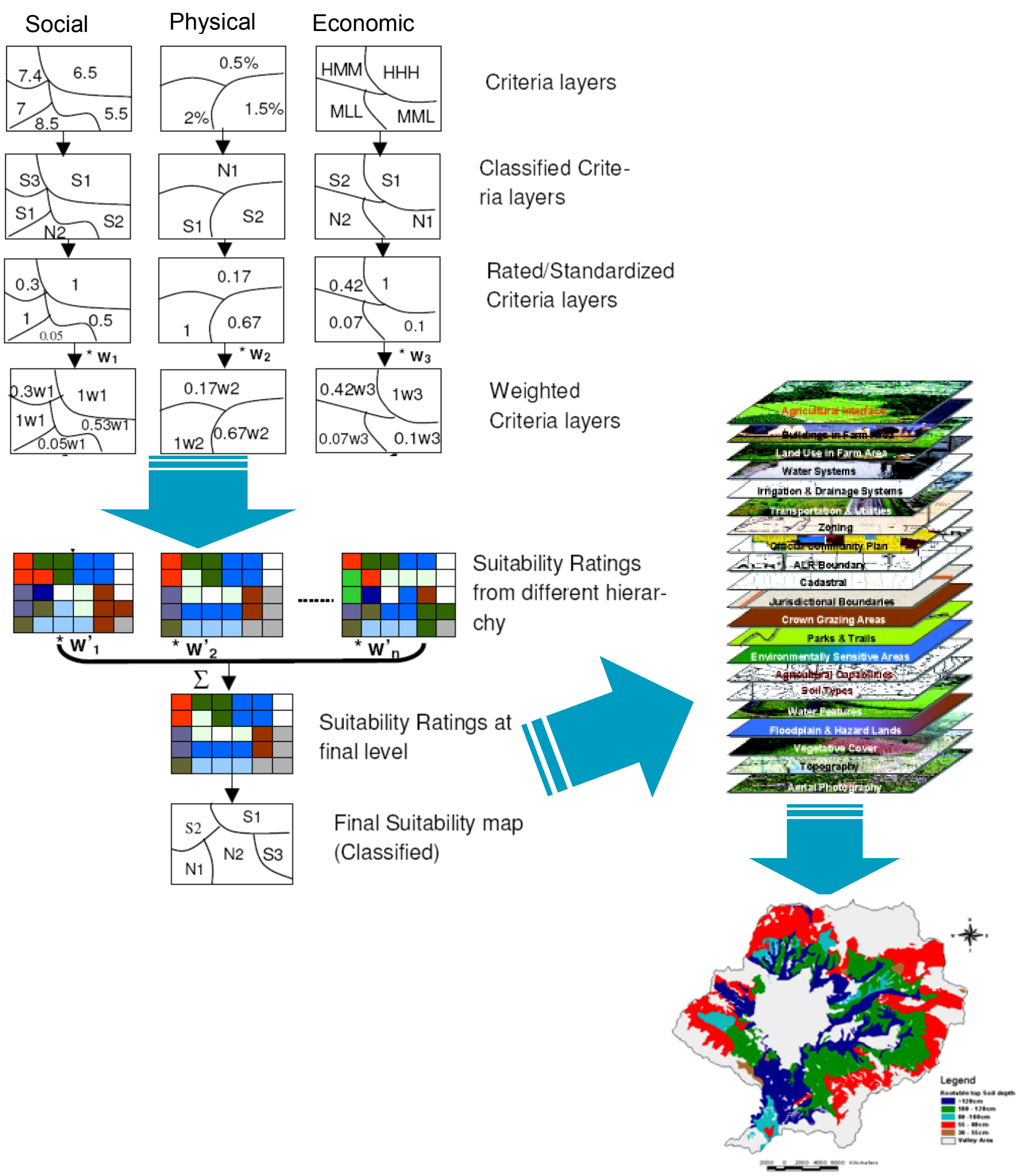


Figure: 4.5 GIS based model for multi-criteria land suitability evaluations for agriculture

5 BACK GROUDND OF THE STUDY AREA

Brief Description of the study area in general is presented in this chapter. Attributes of the study area has marked effects on the tradition and culture and in turn to the cultivation practices. So the result of the data collection is influenced by characteristics of farmers, climate and topography research locations. The information presented in this chapter would show the basic facts to be considered for the data analysis and interpretation of the results. Being one of the mountainous areas and rough topography, consideration of the study area information is of prime importance. This chapter also includes information from the socioeconomic, demography, Meteorology and vivid dimensions

Today, the Kathmandu valley faces a number of serious environmental and ecological challenges. The ecological degradation in the hills and the rapid degradation in the quality of the urban environment, including riverine ecology, have raised concerns both at home and abroad. Rapid environmental issues addressed by the Nepal Environmental Policy and Action Plan (NEPAP), which were endorsed by the Environmental Protection council, Nepal government in September 1993. The development and implementation of an environmental action plan for the valley is identified in NEPAP as a priority area of action.

5.1 Outline of Physiography of Nepal

Nepal, with its land area of 147,181km^2 between the latitudes of $26^{\circ}22$'N and longitudes of $80^{\circ}04$' E occupies the central third of the massive Himalayan chain 2500 km long. It has a length of about 885km, and an average width of 193km.

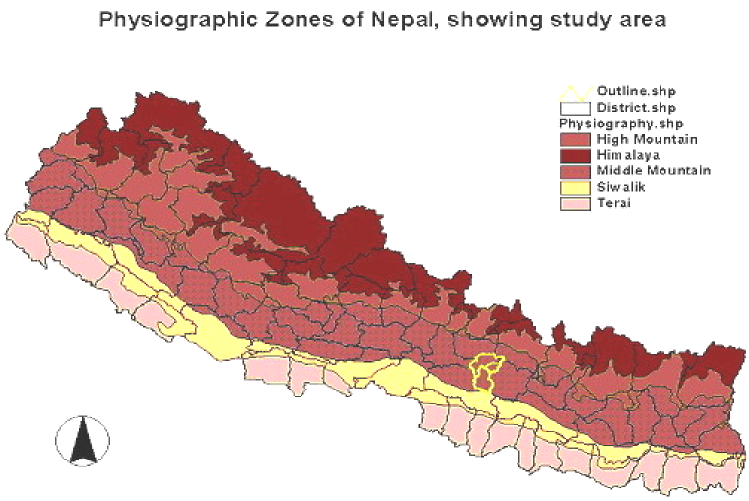


Figure: 5.1 Map of Nepal showing physiographic zones with outlined administrative boundaries.

Physiography

Nepal endowed with rugged hills and mountains that covers more than 80% of the lands has eight of the world's 10 highest peaks including Mt. Everest at 8848m. The extreme range of topography results in a wide variety of climatic conditions ranging from the tropic in the south to the upper tree limit and perennial show, within a horizontal distance of less than 150km. Land Resources Mapping Project (LRMP, 1986) with Master Plan of Forestry Sector, 1988 categorized Nepal into five broad physiographic categories as follows

A*)* Terai*:* The Terai occupies the southernmost part of Nepal. It stretches from east to west. It comprises 12% of the total area of Nepal. Altitude varies from 60m to 300m above mean sea level. Conditions in the east are more tropical than in the west: Mean annual precipitation in the far western 1547mm where as Jhapa in the Far East has 2000mm.

b) Siwaliks: The Siwaliks or Churia hills are the smallest and youngest range of the Himalaya. They enclose some elongated east to west running cultivated valleys known as the inner Terai (Bhitri Madesh) and some intricately dissected outwash plains. Altitude varies with in the west the peaks being at around 1500m with a high point of 1800m and in the east between 500 and 700m high. The Siwalik range occupies 13% of the total area of the country.

c) Mid Mountain: Mid-mountains are the great central belt of Nepal. It extends to about 30% of the country and is composed almost entirely of a network of ridges and valleys. It contains less than 5% of the flat land. Scarcity of land has made farmers here use slopes that are intricately interwoven with extensible terraces system. The highest points are in the ridges that extend down from the high mountains (3000m)

d) High Mountains: The high Mountain zone occupies 20% of the country. Its upper boundary is the forest line at about 4000m. The High Mountains slopes are long, straight and steep that makes them quite sensitive to erosion resulting high rates of sediment delivery.

e) High Himal: High Himal zone occupies 23% of Nepal. It lies between the upper limits of forest vegetation and the crests of the Himalaya. Overgrazing has eliminated forests from many of the valley slopes and bottom lands.

Table: 5.1 Physical specification of Nepal

Characteristic	Terai	Hills	Mountains	Nepal
Area (km^2)	34,019	61,344	51,818	147,181
Area (%)	23.1	41.7	35.2	100
Population (%)	48.5	44.2	7.3	100
Eastern Development Region (%)	14.3	7.1	1.7	23.1
Central Development Region (%)	17.0	15.3	2.4	34.7
Western Development Region (%)	7.5	12.0	0.1	19.6
Mid-Western Development Region (%)	5.3	6.3	1.3	12.9
Far-Western Development Region (%)	4.3	3.5	1.7	9.5
Density (per km2)	330.78	167.44	32.62	157.73

An out line of agro-ecological setting of Nepal

Nepal enjoys a monsoon type of climate with wet summers and dry winters. Maximum rainfall occurs during June to September. Southern slopes of the himalayan mountain receives higher rainfall (3477mm in Pokhara) while Jomsom lying north of the main Himalayan range receives 295mm. Temperature variation with change in altitude also has marked effects on the cropping pattern and crop production. Given the tremendous diversity of landscapes and climate in Nepal, own system for classifying agro-ecological zones. For such a system to be useful it must a) reflect as nearly as possible the biophysical constrains b) be simple enough to focus on optimum land resource development. c) use existing classification system d) delineate clearly defined altitudinal zonation and e) assist planners in providing justification for natural resource development (Carson 1992).

Based on physiography, delineation of presently cultivated area, and altitude, four distinct agroecological zones can be identified with different potentials for vegetable production (PACMAR and EC 1991).

1. **Tropical Zone:** The tropical zone runs east-west along the southern part of Nepal, with elevation ranging from 60 to 1000m. The temperature fluctuates between 7° and 24°C in December-January and between 24" and 41°C in June-July, with the mean temperatures around 20-24°C. Annual rainfall varies from 1300mm in the east to 600mm in the west. This climate is found in some parts of the mid Hills and

Siwaliks and all parts of the Tarai. This zone accounts for about 60% of the total cultivated land in the country.

2. **Subtropical Zone:** The subtropical zone also runs east-west almost along the middle part of the country with elevation between 1000 and 1500m. Summer is long, humid, and warm, with temperatures of 13-27°C in June-July and 2-17°C in December-January. Annual rainfall varies between 2800mm in the east and 1000 mm in the west. This covers about 20% of the cultivated land.
3. **Warm Temperate Zone:** The elevation ranging from 1500 to 2000m. The weather of moderate type, but there is occasionally snow in the higher areas. The average winter daily temperatures fluctuate between 9° and 10°C in December-January and between 12° and 21°C in June-July. Annual mean temperature ranges from 15° to 17°C, while annual rainfall varies from 900mm in the east to 140mm in the west. This covers about 12% of the cultivated land. The most commonly grown vegetables in this zone include cauliflower, cabbage, radish, broad-leaf mustard, and potato. Road access is even more limited in this zone, which means there are fewer accessible commercial production pockets.
4. **Cool Temperate Zone:** In the cool temperate zone, elevation ranges from 2000 to 3000m. Temperatures are usually low and there is snowfall every year. Mean annual temperatures range from 10° to 15°C. This zone has about 1.5% of the total arable land. Fresh vegetables and virus-free, good quality vegetable seed can be produced. Commercial production is constrained by lack of roads in this zone.

5.2 An overview of Nepalese agriculture

For the purpose of the 2001/02 Agriculture Census of Nepal, an agricultural holding was defined as an economic unit of agricultural production under a single management comprising all livestock and all land used wholly or partly for agricultural production purposes. In Nepal it is not uncommon that an agricultural holding is equivalent to a farm household. There were 3.3641 million agricultural holdings identified from the listing operation. In a span of ten years, the number of agricultural holdings increased by 22.8%, an average annual increase of 2.3% which is also almost the same rate of increase in the population. There have been a decreasing proportion of households that operated agricultural holding between 1991/92 and 2001/02 in Nepal from 82.2% to 79.1%. The decrease in the proportion of households operating an agricultural holding was felt most in the hill ecological belt. The proportion of households who operated an agricultural holding even increased slightly to 75.8% in 2001/02 (CBS 2006). The population census 2001 has put the farm population count at 19.0325 million people. There has been a decline in the proportion of the farm population to the total population in Nepal from 87.9% to 82.2% in the period of 10 years from 1991. Same pattern is observed among all the development regions of the nation.

Agriculture census revealed that there were 3364.1 thousand land agriculture land holdings in Nepal, of these 3337.4 thousands holdings were with land area of 2,653.9 thousand hectares. A total of 26.7 thousand agricultural holdings were without land. Numbers of agricultural land holdings are increasing in every successive decade. Similarly total area of land holdings has been increasing steadily. Figure shows that it has increased by 57.5% over 40 years. There was a big increase in the area of land holdings between 1971/72 and 1981/82 censuses. In last decade number of agricultural land holdings without land has decreased to 26.7%. There is a steady increase in the total land area of the holdings, the average area per holding which was 1.11 hectares in 1961/62 decreased to 0.80 hectares in 2001/02. This is expected because the increase in the number of agricultural holdings was faster than the increase in the total area of all holdings in the country.

Table: 5.2 Size of holdings in Nepal

Classification	Census year				
	1961/62	1971/72	1981/82	1991/92	2001/02
Total Holding	1540.0	1721.2	2194.0	2736.1	3364.1
Holdings with land	1685.4	1654.0	2463.7	2597.4	2653.9

Source: CBS, 2006

The farm size in Nepal is becoming smaller. Almost three-fourth (74.7%) of the holdings reported less than a hectare in area in 2001/02 compared with 69.5% in 1991/92 and 66.6% in 1981/82.

5.2.1 Characteristics of agricultural holdings and holders

At the national level 78.2% of the total holdings reported that their agricultural produce was used only for household consumption while 21.6% of the holdings used for both purposes-consumption and sale. Summary of characteristics of agricultural holders and holdings is presented in table 5.3. In 2001/02 about 39.8% of the total holdings reported that their agricultural produce was sufficient to feed the house hold throughout the agricultural year while some 60.2% of the total holdings reported that their produce was insufficient to fee the household for the whole year.

Table: 5.3 Summary tables of characteristics of agricultural holders and holdings Nepal

SN	Description	2001/02
A	Percentage of Male agriculture holders	91.9
	Percentage of female agriculture holders	8.1
B	Average size of male holdings	0.81
	Average size of female holdings	0.53
C	Use of produce of male holdings	
	a. Home consumption	78.2
	v. Home consumption and sale (both)	21.8
D.	Sufficiency/Insufficiency of agricultural produce (%)	
	Sufficient to feed household	39.8
	Insufficient to feed household	60.2
E	Area of holding by soil type (%)	
	a. sand	22.2
	b. Loam	33.3
	c. Silt	6.3
	d. Clay	20.1
	e. Clay-Loam	5.5

Market oriented farming are generally in Nepal managed by farm manager. Appointing manager in the agricultural activities is not much prevalent in context of Nepal. A hired manager is a person who takes technical and administrative responsibilities in the management of holdings on the holder's behalf. There were only 7837 holdings, equivalent to only 0.23% of the total, with a hired manager in 2001/02. Of this number, 104 holdings or 1.33% were without land and 7733 holdings or 98.67% were with land. Land holdings in the Terai belt reported to have highest percentage of hired manager. This can be correlated with the prevalence of higher numbers of commercial farming activities.

Table: 5.4 Farm labour characteristics Nepal

		Census year	
	Description	1991/92	2001/02
A	Total farm population 10 years old and above	11843.5	13954.0
	Economically active population	8379.6	9968.3
	% of total farm population	70.8	71.4
	Net economically active population	3463.9	3985.7
	% of total farm population	29.2	26.6
B	Agriculture Workers (%)	100	100
	a. Holdings employing permanent agricultural works only	1.4	0.7
	b. Holding employing both permanent & occasional workers	3.9	2.0
	c. Employing occasional workers only	30.3	31.1
	d. No workers employed	64.2	66.2
			Figures presented in thousands

Source: CBS, 2004

Number of parcels in the country does not show a particular trend. It has been going up and down in every successive census. At the same time average size of parcel is also changing erratically. The average parcel size was 0.16ha in 1961/62. This value was 0.24ha for 1991/92 and it remained almost constant till now. Number of parcels is more often attributed by rate of process of land fragmentation.

5.2.2 *Land fragmentation in Nepal*

In Nepal there is traditional system of family separation each individual separated family members, especially sons get equal quantity of property including land. This means each fragment of family land is inheritable. As land divided into small parcels, the production efficiency of land increases but input in farm land increased considerable. So, cost benefit analysis goes in negative direction (Upreti and Uprei, 2002). Even though the production are not be enough to support total family for whole year. Then the further family members have two options: either they leave farming and take up industrial or governmental work in cities for additional income, or they sell their lands and migrate to other near by villages where they can buy enough plot of land to continue farming.

Land tenure refers to arrangements or rights under which the holders holds or uses the land of the holding. Land owned but rented out to other is not considered as part of the holding. In Nepal, while the average holding size is small, most of the holdings are owned. The ownership of the holdings under one form of tenure is estimated to be 2,939.6 thousand hactare in 2001/02. It is very popular to rent land are on the share cropping basis. Of the total rented land, 56.5% area being rented at that time (CBS 2006).

5.2.3 Land holdings

Land use refers to the major classification of the use of the different parcels of land in the holdings. All land operated by agricultural holdings is classified as either agricultural land or non-agricultural land. The total area of all agricultural holdings in the country has been increasing (table: 5.5). On the other hand, non-agricultural land are those lands that are part of the holdings that comprise woodland or forest (not commercial) and all other land, unused and undeveloped potentially productive land and all other land in the holding not elsewhere classified including the home of the holder.

Table: 5.5 Summary of land use in Nepal in chronological order

Description	**Census year**				
	1961/62	1971/72	1981/82	1991/92	2001/02
Total area of holding	1685.4	1654.0	2463.7	2557.4	2653.9
Agricultural land	1626.4	1592.3	2359.2	2392.9	2497.7
Arable land	1591.0	1567.0	2287.5	2323.4	2357.0
Agricultural land as % of total area of holding	96.5	96.3	95.8	92.1	94.1
Arable land as % of total area of holding	94.5	94.7	92.8	89.5	88.8
Non agricultural land	59.0	91.7	104.5	204.5	156.3
Non agricultural lad as % of total area of holding	3.5	3.7	4.2	7.9	5.9

Numbers in '000 ha *Source : CBS, 2006*

When agricultural land use in Nepal is concerned, there identified only four major kinds of land use types. This catagorisation has been done in traditional ways and is incorporated within the legal frame work. The properties of such land use type have been based on the land characteristics. These four traditional categories of agriculture land use type are legally recognized by Nepalese Land reform act. Characteristics of each of them are specifically given in table 5.6.

Table: 5.6 Legal land use types in Nepal

Characteristics	Major kind of Land Use Type (LUT)			
	ABBAL	DOAM	SIM	CHAHAR
Main Attribute	Good quality fertile land	Well drain sloppy land	Water logging land	Soil mixed with gravel
Soil	Loam type	Sandy	Clay soil in low land	Gravel texture
Cropping system	Paddy-Wheat	Maiye-mustard	Single paddy	Maize
Land Tax	More	Lesser	Wetland rete	Very low
Assign by society	Cultivation	Cultivation	Wetland crops	Buiding up area

Land under temporary crops is under the category of arable land which is very important in attaining food self-sufficiency in Nepal. Such land is legally denoted as Abbal.

5.2.4 Cultivation system

The total area under temporary corps had increased by 23% between period of 1981/82 and 1991/92 however increment is rather slow between 1991/92 and 2001/02. Among temporary crops, different kinds of vegetables are common commodity in the diet of the Nepalese especially those who are vegetarian by choice. In 2001/02, the number of vegetable growers has not really increased proportionally relative to other temporary crops in the last ten years having registered a proportion of 29.6% in 2001/02 compared with 28.2% in 1991/92. However, if we examine its growth as a group, the number of holdings raising vegetables had increased by 28.2% in the last ten years, from 763.1 thousand holdings to 978.1 thousand holdings in 2001/02. The area used in growing vegetables also increased by 51.9% in the last ten years although proportional with other crops, vegetables growing shares only 1.4% of the total area under temporary corps in 2001/02. Majority of the holdings growing vegetables are found in the hilly belt composed of 53.1% (518.9 thousand) of the total growers but a significant number (387.6 thousand) are found in Terai belt.

Total area under vegetables in 1995 was estimated to be about 144,000ha, only about 4% of the total cropped area. In 1995, total vegetable production, excluding potato, was estimated to be 1.33 million ton, at an average yield of roughly 9.2 t/ha. With an estimated population of 22 million in 1995, annual per capita vegetable availability at the farm level was estimated to be about 60kg (Pradhan and Perara, 2005).

Average area of vegetable crop was only $200m^2$ for the country, which is the same size found in hill and Terai belts. In terms of rate of usage of the vegetable area, the mountain belt holdings reported the highest at 500% followed by Terai belt holdings with 400%. Hill belt holdings reported the lowest utilization rate of 250%. This low utilization rate in Hill belt may be due to the cultivation of long maturing type of vegetables like *Asparagus*.

Tubers group is another group of temporary crops that are equal important to the diet of the Nepalese people. This crop is grown all over Nepal but in small scale. The average area planted was only one tenth of a hectare, which can be considered as subsistence type of farming. Potato, Yam, Taro, etc. are the major crops of this category. In 2001/02 there were 950.1 thousand holdings raising any kind of tubers, most of which are planting potatoes both during winter and summer. The tuber growers comprise about 28.7% of all holdings engaged in raising temporary crops in 2001/02. About 91% of the total tubers crops are occupied by the potato alone (CBS 2006). Spices is one of the cash crops, which is categorized as one of the non food crops that can provide immediate cash income to the farmer since these crops are not for table consumption of the family. Only 14.3% of the totals holding raising temporary crops were engaged in spices growing in the very small aggregate area of 40.7 thousand hectares which is only 1 percent of the total cropped area. Figure shows that there was an increase in the number of holdings growing spices in consecutive years.

There has been an increasing use of chemical fertilizers in the cultivation of important crops in Nepal since 1981/82. It is notable that in the increase in area fertilized were vegetables and maize with 150.5% and 81.6% increase respectively. The use of fertilizers among vegetable farmers is comparatively lower than potato growers both in 1991/92 and 2001/02. Vegetable growers in terai belt still reported to have the highest percentage of fertilizer users compared with the other belts (CBS, 2006). The use of pesticides by crops growers in the 80s decade was practically unknown where the highest percentage was reported among wheat growers with only 1 percent that applied pesticides in their farming operations. Less then 1% among rice, maize, potato and sugar cane growers used pesticides during the same period. Potato growers also increased their utilization of pesticides from 0.5% in 1981/82 to 10.7% in 1991/92 to 19.5% in 2001/02 (CBS, 2006).

5.2.5 Agricultural systems in Kathmandu valleys

Agricultural land dominated the Kathmandu Valley over 35 years ago. The largest conversion occurred between 1991 and 2000. GIS study show that between 1984 and 1998, about 6,300ha of fertile and productive agricultural land were lost to urbanization, industrialization, and quarrying of sand, soil, and stone (IUCN, 2001).

In uplands of Kathmandu Valley there are both subsistence and at semi-commercial systems of vegetable production are practiced. Subsistence farmers generally grow vegetable crops in small areas, mostly mix-cropped with staple food crops for domestic use. Commercial cultivation produces for market consumption. Due to the commercialization, there is a change in the agricultural system from traditional to more specialized monoculture practices. This causes changes in the productivity of crops (Budathoki, 2002). Introduced varieties of seed and agricultural inputs are also in use. Kathmandu valley posses, both urban and peri-urban vegetable cultivation practices. Special peri-urban is more important and cultivated in commercial scale then urban.

Kathmandu valley represents middle hills of Nepal. Hill farmers in general are small scale, resource poor and they farm at subsistence level. Modern technologies offered by various governmental and non-governmental organisations are often inappropriate for them and therefore they cannot reap the harvest of these technologies. Most of these technologies need high external inputs, ideal environmental conditions and good and timely crop management, which is not within the capacity of resource poor hill farmers. However, the hills of Nepal are a good source of local, traditional and indigenous vegetable crops and varieties. These may not be superior, but they are appropriate for the local conditions. Therefore, it is suggested that programs of collection, identification and evaluation of these crops be started however, there are some varieties and technologies that need further research. These activities could be done jointly by research stations, farmers and concerned Agriculture Development District Offices for fast expansion of the appropriate technologies (Budhathoki 1992).

In 1997 HMG/N adopted a 20-year Agricultural Perspective Plan (APP) with the aim of accelerating agricultural growth from about 3% in the first half of the 1990s to 5% in the following 20 years. The APP emphasizes realigning investments in selected priority inputs, particularly: (i) shallow tube well irrigation in the Tarai; (ii) agricultural roads; (iii) fertilizer;

and (iv) technology development and delivery (research and extension). It directs new investments to priority outputs, especially rice, citrus, apple, vegetables, livestock, and forestry products. Agribusiness is emphasized as part of a commercialisation strategy. The increased farm incomes arising out of realigned investments are expected not only to bring direct benefits to the farming community but also to generate strong multiplier effects on growth of output and employment in the rural non-farm sector, as the principal means of addressing unemployment, poverty and environmental degradation. The strategy requires packaging the component parts at the district, village and farm levels. The APP further envisages a decentralized and participatory implementation mechanism that operates at the district and national levels and is complemented by an analytical body at the national level to facilitate reinforcement and adjustment of the plan targets over time. Once implemented this innovative implementation mechanism is expected to constitute a major step towards improved participatory Governance (FAO and UNDP 2003).

5.3 Features of Kathmandu valley

The valley is elliptical in outline 25km along east west axis with maximum width of 19km. The mountain ranges rise rather abruptly on all sides of the valley. These mountains attains heights of 1800m to more in east and west, where as in north and south they culminate in Shivapuri peak (2732m) and Choking peak (3132m) respectively. The grains of geological structures run in east -west direction and consequently several ridges run into the valley in the form of east-west directions. With the exception of Nagarjuna ridge, these ridges seldom rise above 1500m altitude.

Kathmandu Valley lies at 1300m above sea level and is located between latitudes $27^{\circ}32'13''$ and $27^{\circ}49'10''$ north and longitudes $85^{\circ}11'31''$ and $85^{\circ}31'38''$ east. Its three districts, Kathmandu, Lalitpur, and Bhaktapur, cover an area of 899km^2, whereas the area of the valley as a whole is 665km^2. Kathmandu Valley lies in the central hilly region of Nepal (Figure: 5.2). The valley with bowl shape is 19 by 30km. The total area of the Kathmandu Valley is 640km^2. The valley encloses the entire area of Bhaktapur district, 85% of Kathmandu district and 50% of Lalitpur district. It comprises three districts: Kathmandu (395km^2), Lalitpur (385km^2) and Bhaktapur (119km^2). There are 115 VDCs and five municipalities in these three districts. Of these, 25 VDCs are situated outside the watershed boundary of the Kathmandu Valley. These five municipalities are the main growing urban areas of Nepal: Kathmandu Metropolitan, Lalitpur sub-metropolitan, Bhaktapur

Municipality, Kirtipur Municipality and Madhyapur Thimi Municipality, covering an urban area of about $97km^2$.

The net area of Kathmandu Valley which is based on a watershed boundary covers 81% of total area of Kathmandu district, 32% of Lalitpur district, and the whole of the Bhaktapur district (Figure 5.2). At the same way part of the Kathmandu district covers 55% share of the total study area, similarly Lalitpur covers 26.2% and Bhaktapur district covers 18.8% of the potential study area.

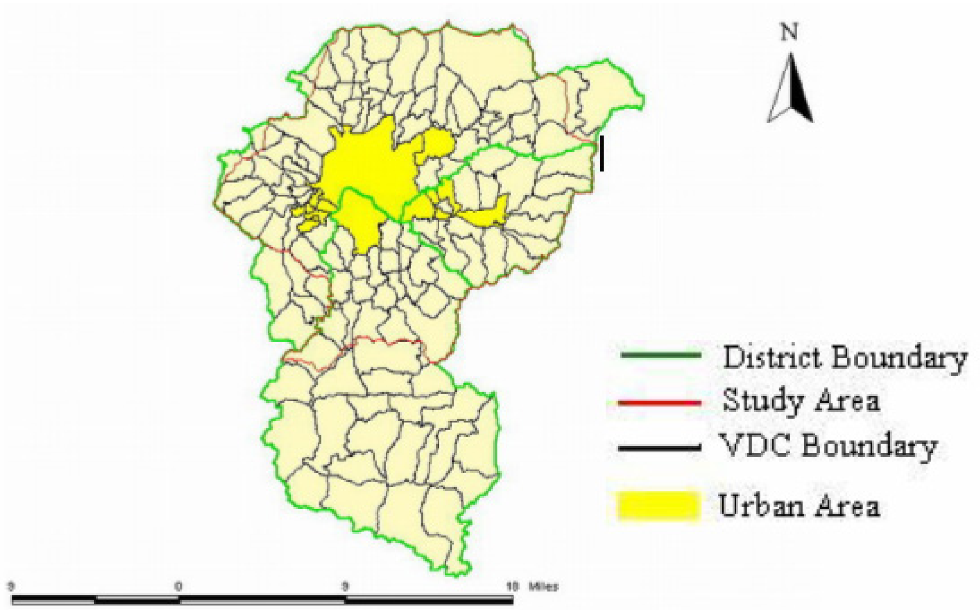


Figure: 5.2 Map of the study area

The valley has tectonic origin (Hagen 1998). The floor of the valley lies at an average elevation of 1250m from the mean sea level from which mountains rise rather steeply on all sides above 1800m the highest being the Phulchoki ridge with elevation of 2831m in the east. The valley floor is made up of fluvio-lacustrine sediments with vertebrate fossils of quaternary age (ESCAP / HMG 1993). Two other distinctive associated physical features of the valley basin are Dol and Tar. The former is an alluvial flood plain, formed by recent alluvia freshly deposited by the rivers while the latter is an elevated terrace or table land and is relatively old. In Kathmandu Valley, elevated terraces are formed in between alluvial flood plains.

Figure: 5.3 Alluvial plains with terraced rice field

The valley is bowl shaped and surrounded by the Mahabharata mountain range on all sides. There are four hills acting as forts of the valley, Phulchowki in the South East, Chandragiri/Champa Devi in the South West, Shivapuri in the North West, and Nagarkot in the North East. The highest altitudes are 2,166m (in Bhaktapur), 2,732m (in Kathmandu), and 2,831m (in Lalitpur).It is surrounded by hill in all the sides and ridgeline of which forms the potential limits of its watershed. The prominent boundary features of Valley inclueds Shivapuri peak (2732m) in the north, Phulchoki ridge (2831m) in the south, Chandagiri lake (2200m) in the south-west, Bad-bhanjyang in the west and Sanga Bhanjyang in the east. It is one of the typical hilli regions. The surrounding mountains also known as Mahabharat range are composed of a thick sequence of meta-sedimentary and metamorphic rocks such phyllites, quartzites, siltstones, schists and marble. These sediments are formed between Precambrian and Tertiary age (HMG / ICIMOD / CDG / UNEP 1994). The hills are generally heavily dissected. The lower and gentler slopes have been used for terrace cultivation and forests are found only on higher elevations.

5.3.1 Regional geology

The alluvium filled valley of Kathmandu is bordered by a sequence of unmetamorphosed to slightly metamorphosed sedimentary rocks of Paleozoic and Precambrian age in south east and west directions. In the north it is bordered by schist, gneiss and granitic rocks. The southern range of Phulchoki and Chandragiri consists of cross bedded radish sandstones and shales, indicating their deposition under oxidizing conditions, perhaps continental. These are overlaid by gray and purple shales, white quartzite, bluish green calcareous shales, and hematite bed. The western range of Bhedunga and Nargarjun, and eastern ranges of Soorya

Binayak, contain a sequence of phyllites, limestone and quartizes. These are some what more metamorphosed. Traces of fossil like markings are known. The calcareous rocks of Nagarjun show ripple marks and are high in sandy fractions where as those of Adeswor are finally bedded and rich in calcium carbonate. These rocks also indicate deposition in shallow waters.

North of this in Mudku-tin Piple and Dhulikhel areas lies sandstone and siltstone which have been partly metamorphosed to phyllites and fine grained schists. These rocks have been described as Precambrian in age. The main hills of Kakani-Shivapuri range, north of Kathmandu are made up of gneissic granite, and gneisses with occasional bands of garnet-sillimanite schists. These are intruded by tourmaline-bearing granites.

The Kathmandu Valley itself is made up of fleuvo-lacu-strine deposits of Pleistocene age, exposed in terraces situated at various altitudes. These are dominantly clay and sands with minor gravel beds. Diatomaceous white clay and minor peat horizons are also present associated with a major formation of vivianite-bearing bluish gray clay. The geological formations of this area are unique in Nepal in having fossiliferous Paleozoic rocks south of the main Himalayan Range. These fossils show affinities with those of Kashmir, Spiti and Northern Kumaon on one hand and those of Shan State of Burma of other. Whether this represents a continuous sea joining these areas in the Silurian age (450 million years ago) is a question beyond the scope of the present paper. After this there is a very big gap in the sedimentary sequence of this area, the next being the alluvium formations of Kathmandu Valley of Pleistocene age (less than one million years old).

What was the factor that caused the formation of alluvium filled valley of Kathmandu is a question which is yet to be answered. It will require some geophysical investigation to establish the nature and configuration of the valley below the alluvium. It is seen that at the northern half of Kathmandu Valley the development of coarse sand of granitic composition is widespread. This reflects the lithology of the provenance (Shivapuri-kakani Range) from where these sediments were derived. In the central area Kalimati (a variety of porous bluish gray clay, which looks black when wet) is well represented. This clay contains traces of vivianite (a phosphate of iron) and some diatoms. In the southern edges of this formation at places, whitish diatomaceous clay is represented. It is locally called 'Kamero'.

In the south pebble beds containing pebble of quartzites and phyllites make a capping on the fine sand. It is well representative in Nakhu Khola area. Apart from this mountain wash and talus of angular materials skirts the valley along the foot of the hills. Lentricular bodies and thin horizons of peat are exposed at various places in the valley most of which are concentrated at the outer edges. Some drill holes ranging from 200 meter to 375 meters in depth were drilled fro underground water. Most of these holes could not reach bedrock. The nature of sediments encountered was in the main similar to those at the surface. A typical drill log at central of the valley is represented below in the table 5.7.

Table: 5.7 Typical drill log in centre of Kathmandu valley at Lagan Tole apprance of horizon in different distance range from the land surface.

Depth Range in Meters	Strata
0 - 10	Sand, vary coarse to fine grained, micaceous, with quartzite pebbles, occasionally.
10 - 221	Clay, dark black, with light greenish dark clay intercalations often in laminated form, occasionally gritty, with green hyalite shale pieces and peat and lignite bands.
221 - 230	Sand, coarse to medium grained with peaty to lignitic clay bands.
230 – 283	Clay, black, plastic, gritty, with sand, consisting of quartz, felspar, muscovite, granite, chips and phyllites chips.
283 - 286	Sand as above, coarse grained, with small gravel essentially quartzite-quartz and felspar with few schistose sandstone pieces.
283 -313	Clay, dark black, very compact sand, with sand fine grained, micaceous and occasionally pebbles (resulting in angular quartz gravel on drilling)
313 -325	Predominately sand, very coarse grained arid pebbles with intercalation of clay, dark black compact of ten gritty and carbonaceous.
325 - 355	Gravel, small sized and sand very coarse grained of the same composition as above with or without lignite and peat.
355 - 361	Clay, dark black, as above, with some gravel in the bottom 2 meters.
361 - 367	Sand, coarse to very coarse grained granitic in composition with thin gravel and clay intercalations.
367 - 376	Clay and sand, as above, intercalated.

Analysis carried out by Geologist P. N. Sharma

The sedimentary in the valley seem to be partly deposited in lacustrine conditions giving rise to diatomaceous clay and partly along meandering rivers in swampy conditions giving rise to peatalenses at several horizons. The Pliestocene age of these deposits in indicated by the presence of fossil teeth of an extinct species of elephant, Stegodan ganesha. It shows that conditions were suitable for the elephant to ream in the valley in Pleistocene.

5.3.2 Climate

The Kathmandu valley belongs to the sub-tropical to temperate physiographic zone. However, topographic setting causes to have great variation in climatic condition between the valley basin and the surrounding hill ridge. The broken topography of mountainous regions creates a complex mosaic of topoclimates. Spatial analyses of many climatic elements on a horizontal planar projection of such topography are almost meaningless. Therefore, consideration of the vertical dimension (elevation) for spatial analysis of climate in Kathmandu valley is an important matter. Climate data for the study area has been collected from 16 different weather stations scattered within the valley (table 5.8). Stations are situated in different altitudinal range.

Table: 5.8 Meteorological stations in Kathmandu Valley

MsId	Station	Altitude (m)	Longitude	Latitude
1007	Kakani	2064	85.250000	27.800000
1015	Thankot	1630	85.200000	27.683333
1022	Godavari	1400	85.400000	27.583333
1029	Khumaltar	1350	85.333333	27.666667
1030	Kathmandu	1336	85.366667	27.700000
1035	Sankhu	1449	85.483333	27.750000
1039	Panipokhari	1335	85.350000	27.733333
1043	Nagarkot	2163	85.516667	27.700000
1052	Bhaktapur	1330	85.416667	27.670000
1059	Changunarayan	1543	85.416667	27.750000
1060	Chapagaun	1448	85.333333	27.600000
1061	Lubhu	1341	85.383333	27.650000
1071	Buddhanilkantha	1350	85.367000	27.783333
1073	Khokana	1212	85.283333	27.633333
1074	Sundarijal	1490	85.416666	27.766666
1075	Lele	1590	85.283333	27.583333

Precipitation

According to Department of Hydrology and Meteorology (DHM), mean annual precipitation at the study area ranges between 1500mm to 2000mm and an average rainfall of 3220mm annually for long period of time. The valley receives south-east monsoon is the main rain bearing wind which delivers about three fourths of the total rainfall during the wet summer seasons i.e. June thorough September. While the winter months remain mostly dry, occasional precipitation occurs in the form of winter rains caused by westerly cyclones (Suman, 2004).

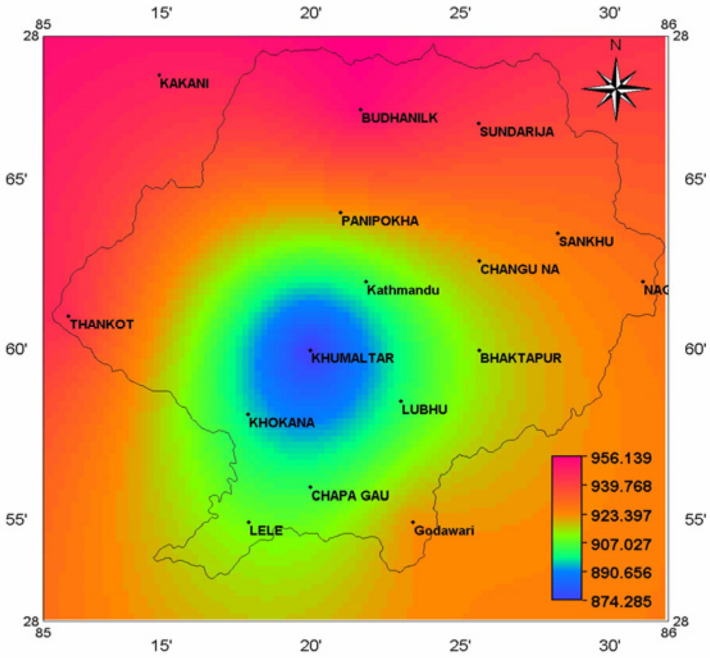


Figure: 5.4 Spatial distribution of precipitation (*Source: Suman, 2005)*

Rainfall in the valley is not evenly distributed within geographical range of the valley. The highest precipitation is normally occurring on the southern slopes of Shivapuri peek (2732m). The amount declines considerably from the surrounding ridge to the valley bottom with decreasing trend at Nagarkot, than at Godavari and finally lowest at Kathmandu foot plains. However, the rainfall in the hilly areas was found almost double to the rainfall in the valley floor. About 80% of the annual rainfall was found to be occurred in the monsoon season. In an average 37% of the days in a year were rainy days in the valley.

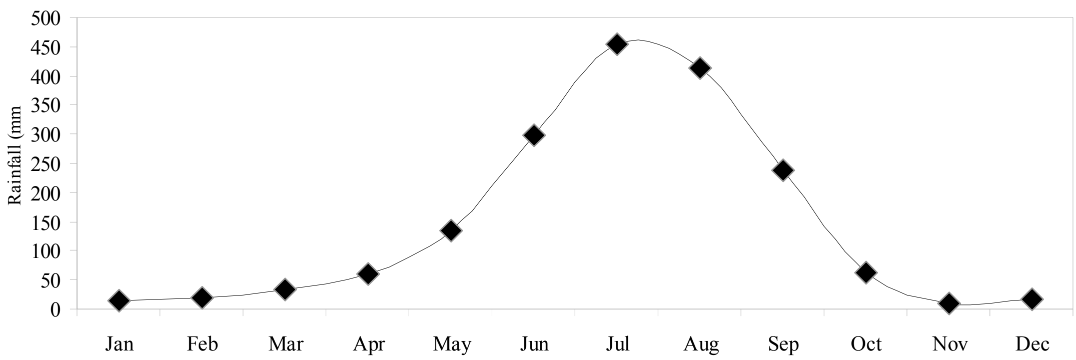


Figure: 5.5 Average monthly precipitation in Kathmandu valley

Temperature

Minimum temperature at the study area ranges from 0°C to -4°C. Similarly, maximum temperature ranges from 26°C to 30°C.Elevation is the main influencing factor on temperature, together with geographical location and aspect. About 99% of the variation in temperature can be explained by elevation and geographical location, and 90% by elevation alone. In Kathmandu valley, the observed average lapse rate for the period from 1992 to 2002/03 was -0.5°C/100m on the basis of annual data. 16 climatological stations at study area are considered. All available mean monthly maximum and minimum temperature values from 1992 to 2001-2003 are complied. For other stations, the maximum and minimum temperatures were estimated using the temperature model. The average monthly temperatures from 16 different stations are presented in figure 5.6.

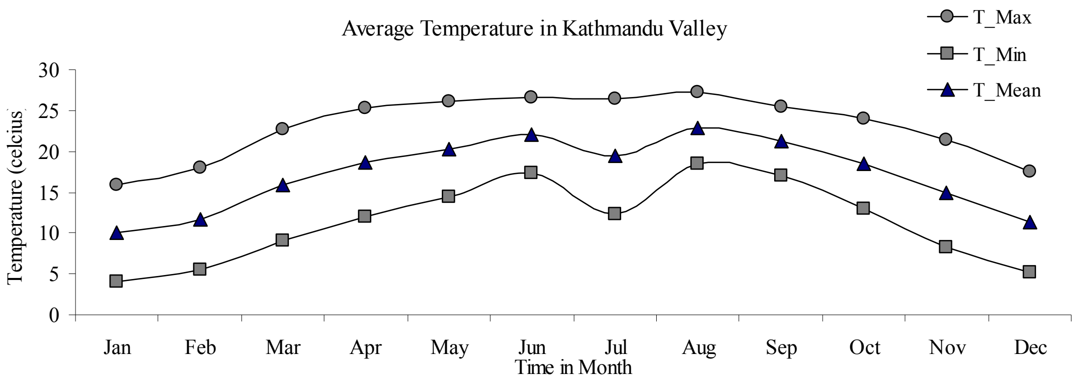


Figure: 5.6 average monthly temperature of Kathmandu valley.

From the available temperature data analysis in the Kathmandu valley, slight increasing trend was observed over the period from 1992 to 2003. Mean annual temperatures in this period were about 18°C to 19° C at the valley floor and about 14.5°C to 15.5°C at Nagarkot, the higher elevation station considered for the study. The maximum annual temperature reached up to 32° C (26.7) with a lowest value of 24.7°C. The minimum annual temperature ranged from 0.7°C (11) to 12.6°C. From the analysis of temperature data of last 10 years, it was found that for mean monthly temperature it is increasing and reaches up to 32°C at Kathmandu Airport in 1999, for mean monthly minimum temperature it is decreasing and falls up to 0.7°C – 0.9°C at Khumaltar station during 1995 to 1999 A.D.

Within a year, there is a temperature variation between average temperatures of 9.7°C in January to 22.2°C in July measured in Kathmandu airport station and between 9.76°C in January to 24°C in July measured in Khumaltar station. The highest maximum temperatures are measured in May to June months, in the pre-monsoon season, although the highest average temperatures are usually observed in the monsoon season. This is mainly due to the increased cloud cover during the rainy season. In the pre-monsoon season cloud cover often breaks up and allows full sunshine and heating up the air. The diurnal temperature range or variation in the summer is small because nights are usually warm. While in winter as nights are usually cold the diurnal range of temperature is greater. The range is greater for Kathmandu core area than for higher elevation stations. Kathmandu core area has an annual range nearly twice as high (14.3°C) as that of high elevation stations.

Wind Speed

Wind was classified as light, medium and strong wind due to the limited data (Nayava, 1981). DHM has published wind speed data only up to 1990. Wind speed in the valley was only published for very few stations. The wind speed data measured at some of the 6 stations are used to plot chart, shown below.

In Kathmandu valley, Maximum wind speed is 170.23km/day in the month of April and Minimum is 101.5km/day in the month of September. In Kathmandu Valley most of the days have a daily wind speed of 1 to 1.5m/s. The average wind speed is 127.09km/day.

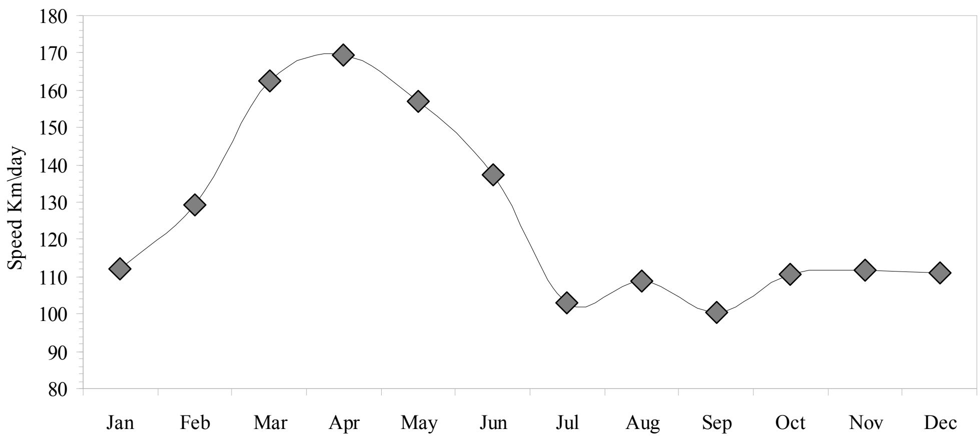


Figure: 5.7 Average monthly wind speed of Kathmandu valley.

Relative Humidity

Average mean monthly relative humidity for 08:45 and 17:45 NST have been tabulated for the periods from 1992 to 2002 for all the 6 stations in Kathmandu valley. The relative humidity in January (minimum) ranges between 70% to 80% and that in July (maximum) is greater than 85%. The average of the relative humidity taken at the above mentioned hours is taken as the mean relative humidity. The spatial variability of this parameter is too high and cannot be estimated from the single location. Therefore the FAO (1998) method was used to determine relative humidity from the maximum and minimum temperatures measured at each site.

Solar Radiation and Sunshine Hours

Total sunshine duration has been derived for the formula presented by Frere and Popov (1979) reference of latitude and longitude of the location. Calculation shows that photoperiod extends from 13 hour 52 minutes in June to 10 hour 24 minutes in the winter day of December. There are 2 stations which have records of sunshine hours in Kathmandu valley used for the study. The cloud cover itself is an important factor in the amount of radiation that reaches the earth‘s surface and actual sunshine hour calculation.

Evapotranspiration

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration (ET). ET varies regionally and seasonally; during the drought period it varies according to weather and wind conditions. It also alters with the elevation, surface steepness (slope) and surface orientation i.e. aspect (Shilpakar, 2003). The highest annual ET is 1492mm/year and lowest goes as low as 262mm/year for Katmandu Valley (Suman 2004). The higher variation in ET in the mountain environment is mainly due to higher variation in solar radiation resulting from surface steepness and orientation.

Lambart and Chitrakar (1992) studied the potential evapotranspiration of Nepal had concluded that the PET values for each month regressed against elevation (which ranged from 100 to 3700m) give quite consistent, good correlations (r^2 ranging from 0.61 to 0.89). Recently, WELINK(1998) has used only light wind in all the ET Calculations in the gandaki Water Basins study. FAO‘s method (1998) assumes that the dew point temperature is close to the minimum daily temperature and therefore uses this value for the estimation of the actual vapor pressure.

Spatial Distribution of ET

The spatial distribution of evapotranspiration in the Kathmandu valley show ET lapse rates varied between about 18mm and 42mm per 100m decrease in elevation during the study period from 1992 to 2003. On an average, the reference evapotranspiration is estimated to change at about 28 to 32mm in every 100m elevation difference (Shilpakar, 2003).

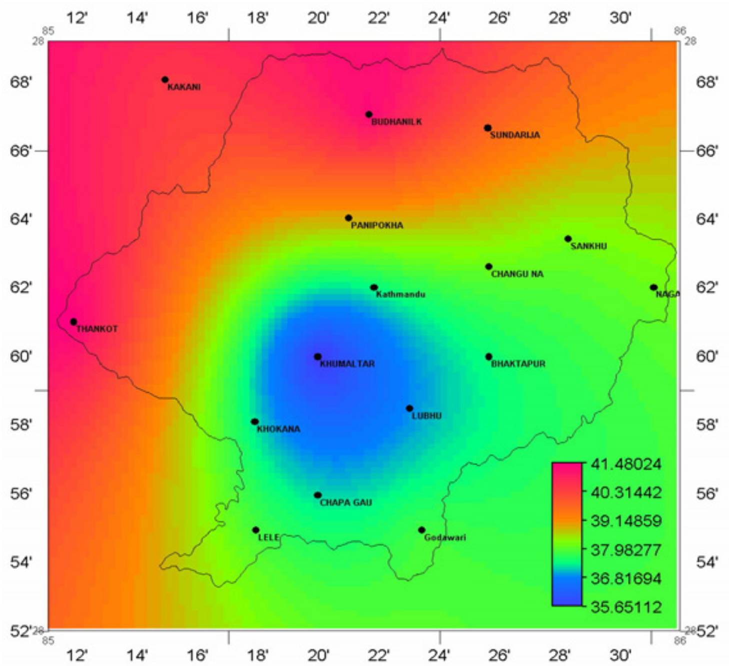


Figure: 5.8 Spatial distribution of evapotranspiration (*Source: Suman, 2005*)

Pan evaporation method may help to determine rough crop water requirement. In Kathmandu, general estimation shows that there accounts eight months of high ET and less rainfall. This condition may lead to water stress situation.

5.3.3 Water Resources

Water, a basic need for survival, is in constant short supply in the Kathmandu valley. Formally, the Bagmati River and its tributaries were able to fulfill the irrigation, drinking water and other needs of the valley. Water demand for domestic use has increased due to the high population growth, while the increasing numbers of industrial, tourism and institutional establishments have put tremendous pressure on the already diminishing water sources. Alternative sources of ground water abstraction are also limited due to the geological condition of valley's sub-strata. In order to increase the water supply to meet current demands, water sources outsides the valley needs to exploit. At the same time water resources present within the valley needs to be handled wisely with proper management.

River System

The Bagmati River system originates at Bagdwar, about 15km north of Kathmandu city, in the Shivapuri hills (2723m). the major tributaries of the Bagmati river system are a) Bishnumati, Tukucha khola, dhobi Khola, Bagmati, Manahara and Hanumante, all flowing from the north and northeast part of the valley, b)Nakhu Khola, Khodku Khola, Godawari and Gundu Khola, from the south and c)Tribeni khola and Balkhu khloa from the western part of the valley. The total drainage outlet at chobhar is 585km^2, while the Bishnumati River has the highest drainage outlet at 103.4km^2 and Dhobi khola the lowest at 28.9km^2

Table: 5.9 River System of Kathmandu Valley

Name of river	**Length** (km)	**Elevation** (m)	**Origin**	**Name of** river	**Length** (km)	**Elevation** (m)	**Origin**
Bagmati	35.5	2732	Shivapuri Bandar	Manamati	6.1	2000	Bhandari danda
Bishnumati	17.3	2300	Shivapuri tarebhir	Manohara	23.5	2375	Manichur danda
Bosan	6.1	1800	Pokhari bhanjyang	Matatirtha	5.0	2000	Matatirtha danda
Dhobi	18.2	2732	Shivapuri danda	Nagmati	7.9	2443	Shivapuri danda
Godavari	14.8	2200	Phulchoki danda	Nakhu	17.6	2200	Bhardeu ridge
Hanumante	23.5	2000	Mahadevpokhari	Samakhusi	6.4	1350	Dharampur-east
Indrawati	16.8	1700	Dahachok danda	Sangla	10.7	2000	Aale dnada
Indrayani	7.0	2000	Bhangari danda	Syalmati	4.8	2200	Shivapuri danda
Kodku	14.9	2000	Tileswor danda	Tribeni	10.7	1700	Bhirkot
Mahadev	9.2	2000	Aale danda	Tukucha	6.4	1325	Maharajganj

Source: Pradhan 1998

The general slope of the valley area is towards the central part and hence to the south-west. All the tributaries flow centripetally towards the centre of the valley to meet the Bagmati. During monsoon season the rivers get flooded and deposited enormous amount of sands and fine particles over the banks. In dry season, their water level is unusually small despite they are perennial. Besides rivers, there are other water sources such as ground water and springs in the valley. The total annual runoff of the Bagmati River at chobhar, the outlet point, is estimated to be approximately 500 million cubic meters, with a mean annual flow of 15.5m^3/s between 1963 and 1980. The maximum mean monthly average discharge of 53.4m^3/s occurs in August and the minimum of 1.55m^3/s in March. However there is a significant fluctuation in the annual discharge, the range being 9.3m^3/s in 1969 to 23.2m^3/s in 1975.

Most of the rivers that flow through urban Kathmandu are now polluted and are unsuitable for drinking and other domestic use. Pollution is primarily attributed by mixing of sewage and industrial effluents. The increasing population density in Kathmandu valley, in the absence or lack of suitable urban planning, a haphazard manner and large-scale encroachment in the floodplain of the river systems are clearly evident problems. Squeezing of natural river channel and construction of human settlements near flood plains of Bagmati, Bishnumati and Balkhu rivers are the major causes in deepening of the river channel. This accelerates the soil loss rate (Ranjit and Shakya, 2005).

It is estimated that about 135000tones/year (Binnie, 1988) to 760,500tones/year (SMEC, 1992) of sediment passes through the valley. Due to landslide, erosion and bank cave-ins with land washouts on the riversides; the sediment transport is higher during times of high flood. Besides this, the forest area of the surrounding watersheds decreased by 40% from 1955-1996. The watershed of the Bagmati River and its tributaries are deteriorating. Hydrologic cycle of the valley is being affected after rapid devastation of the forests in the valley area.

The valley has also witnessed an increase in industrialization and commercialization. The number of manufacturing establishments has gone up from 608 in 1976 to 2142 (with more than 10 persons employed) in 1993. Manufacturing establishments, which has grown quickly and haphazardly in the past decade, have contributed to the valley's economic growth but have also contributed to unplanned urbanization and pollution on prime agricultural land. Manufacturing establishments in the valley have contributed significantly to water and air pollution. Industries often overlook the regency to maintain built-in-pollution control mechanism in their establishments. Quarries such as the Godavari marble quarry and many other smaller units scattered throughout the valley, and the practices of cement factories, brick factories and other industrial establishments, have also caused continuous degradation of the valley's unique geography and threatened the valley's tar (uplands) ecosystems including surrounding hills.

5.4 Forest vegetation and biodiversity

The forests on the valley floor and around the valley rim provide basic needs to rural communities. However, raid, haphazard urbanization, high demand for forest products, illegal and unregulated quarrying has depleted much of the forest vegetation except in protected forests. The major ecological implications are loss of vegetation, declining recreational sites and decreasing water resources.

In 1996 forest land covers 20,945ha (32.7%) of the total area of the Kathmandu Valley. Land use changes between 1984 and 1996 show that the quality of forests has greatly declined with a significant depletion in biomass. There has been a significant increase in shrub land. Gradual conversion of forest into shrub land and then to grasslands is very rapid. It was estimated to be 6 fold more than last decade (interpretation of digital data).

Figure: 5.9 Agriculture land invading forest area

The forests in and around the valley of Kathmandu provide basic needs to rural communities, clean water for valley residents, and recreational sites for tourism in addition they also help in situ conservation of biological diversity. The natural vegetation, except in a few conservation areas, has been under intense pressure. The area under natural forest cover, excluding shrubs, is 10847ha. Conversation of natural forest into shrub land causes increase into shrub land area presently is estimated into3688.4ha. In total only about 25% natural forest area is remaining in the valley. This fact suggests that part of the natural vegetative area also under active urban sprawl. Natural mature hardwood forests are now confined to parks and sacred areas such as Nagarjun (Raniban), Gokarna and Shivapuri watershed and Wildlife Conservation forest, and Bajrabarahi forest. Quarries cover 84ha of forest land in the valley (MoPE, 2003).

Forest vegetation types

The main vegetation types prevalent in the valley are as follows;

1. *Schima-castanopsis* association on the valley floor and hill slopes,
2. *Pinus roxburghii* on the lower hill slopes and on the southern aspects such as Bhobhar, Jargajun, Nagrakot, Bisankhu and so on,
3. *Quercus lanata* dominating the upper hill slopes of Phulchoki, Shivapuri and Chandagiri,
4. *Quercus lamellose*-Lauraceae in the middle of Phulchowki,
5. *Quercus semecarpifolia* is abundant in the hill slopes of Shivapuri and Phulchowki
6. *Rhododendron arboretum* on the upper raches of the valley hills eg. Phulchowki

Forest stock of the valley is not in good condition. *Quercus and Rhododendron* have more than 70% crown cover whereas most of the natural *Pinus roxburghii, Schima-Castanopsis* forests have less than 40% crown cover and are rapidly turning into shrub land. About 1,312 plant species belonging to 162 vascular families are found in the valley, representing 26% of the total of plants recorded in Nepal (KVWMP, 1994). Among 256 species of birds about 33 bird species have disappeared from the valley due to habitat destruction. Most of the quarries are located in medium to steep slopes and cause considerable damage to the adjacent areas.

Some smaller scattered patches of forests found in the valley which are about 25-30 patches. In 15 VDCs no forest stand exists. Majority of the patches possess of *Pinus roxburghii* species of reforested stands. Trees are planted along the roads in the urban areas but are poorly managed. They are mostly of *Eucalyptus, Protea sp, Jacaranda sp,* and Camphor.

The depletion of vegetation cause eco-degradation in the valley, resulting in a) as unbalanced hydrological cycle, b) loss in plant and animal species, and c) landslides, slips and gullies. Since 1996 there were no significant changes in the forest land of the valley because public forest had already used by local people to certain extent and remaining forests stocks are been conserved under community management i.e. community forestry.

Utilization and management of forest resources

Fuel wood is the main sources of energy for cooking in rural households. People harvest directly from the forest.

In some of the forest around the valley is devastated for the charcoal making, timber extraction, uncontrolled livestock grazing, etc. This adversely effects on growth and natural regeneration.

5.5 Erosion level

With increasing demand for high quality vegetables, new land areas (inevitably with steeper slopes than presently under cultivation) are being opened, despite difficulties in crop management practices. The dissected land morphology of the highlands, often with cultivated slopes of up to 30°, and intense rainfall (2500-3000mm year) largely confined to the rainy season, are conducive to serious soil erosion which, besides causing a loss of soil fertility which results in declining crop productivity. Seasonality in the harvest of cabbage and cauliflower has the greatest influence on exposed cultivated land area, particularly since farmers are accustomed to collect and remove crop residues from their fields (Midmore at.al., 1996). Rill erosion is considered the most serious.

The deteriorating condition of the watershed in the valley is mainly attributed to anthropogenic cause. The Kathmandu Valley Watershed Management Project (KVWMP, 1994) identified 23 sub watersheds in the valley. It is estimated that the soil loss on sloping terraces, shrub, and landslide areas is 40mt, 32mt and 200mt/ha respectively. There is an urgent need to assess the ecological effects of such activities, especially in the forest areas. Certainly, the long term loss will be much greater than the immediate economic benefits.

Based on the experience of topsoil it is assumed that more eroded soils would have lower clay fractions and higher sand fractions. Clay content in the soil of Kathmandu valley is decreasing with increase of altitude and slope (Baniya, 1995). This signifies the extent of the erosion in valley landscape. Data on the percentage of clay in soil from farms gives an idea of soil erosion.

5.6 Vegetable markets

One of the important government policies in the Eighth Five-Year Plan is to improve the agricultural marketing system through government and private sector participation (NPC 1992). The plan recognizes that it will not be possible to increase vegetable production and consumption in the country unless appropriate marketing infrastructure is developed and other related support is provided. Basically, there are two types of vegetable markets:

1. *Producers' supply markets:* It is generally located in the vicinity of production pockets. Here producers bring product to deal with middleman and also for sale to wholesalers
2. *Consumer markets*: It is located near major urban centers or urban market centers and gets supplies from producers' markets as well as from out side. Involvement of wholesalers and commission agents will be there. The marketing channels for vegetables differ by the origin of the product. Also, there are different systems for each type of vegetables. Some of the market channels are:

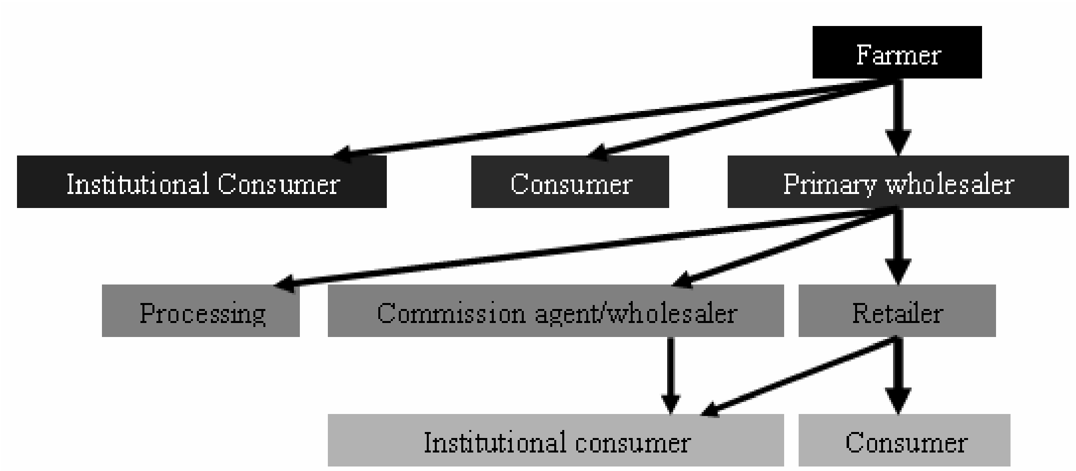


Figure: 5.10 Marketing channels for tomato in Kathmandu

It is found that marketing channel is one of the prime concerns of the producers. Involvement of the middle man is not preferred to the small holding farmers because of output of the product is lowered. However farmers producing in commercial scale has obligation to make use of middleman because of regular and in time marketing.

From the official record of the Kalimati Vegetable and Fruit Market Development Board (KFVMDB, 2007) total vegetable import in 2006 was 1849.24278Mton and in 2005 it was

1315.26691Mton. This scenario shows that there is increase in the vegetable import per year. It appears from the data analysis from different sources as well as GIS data analysis as well the land area is decreasing inside the Kathmandu Valley and simultaneously population pressure increasing. This creates more dependency on the vegetable on neighboring districts. Local farmers sell their production on their own, without passing through any marketing channel. Such marketing do not have any records, so it makes problem to make marketing assessment. Present shows that less than 5% farmers go through this channel and it takes less than 3% share of channalised marketable vegetables amount.

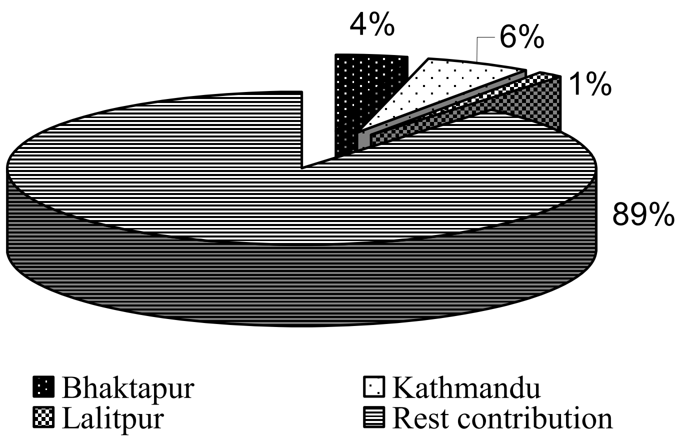


Figure 5.11 Share of vegetable arrival in Kalimati contributed by valley districts

Figure 5.11 shows that only in Kathmandu District, about 90% vegetable come from outside the valley. All together some one tenth of the total consumption in the valley has been supplied by within the valley. But market study of all three districts indicates that about 72% of demand fulfilled by the import from outside including India and Tibet and about one fourth is produced within the valley. This reduced production is neither because of the lack of the availability of the sufficient land resources, not faulty cultivation method, but technically sound cultivation with realization of the land capability is not properly addressed. Therefore, research like present study with well addressed land suitability situation is much relevant to enhance productivity and to meet growing demand of the valley.

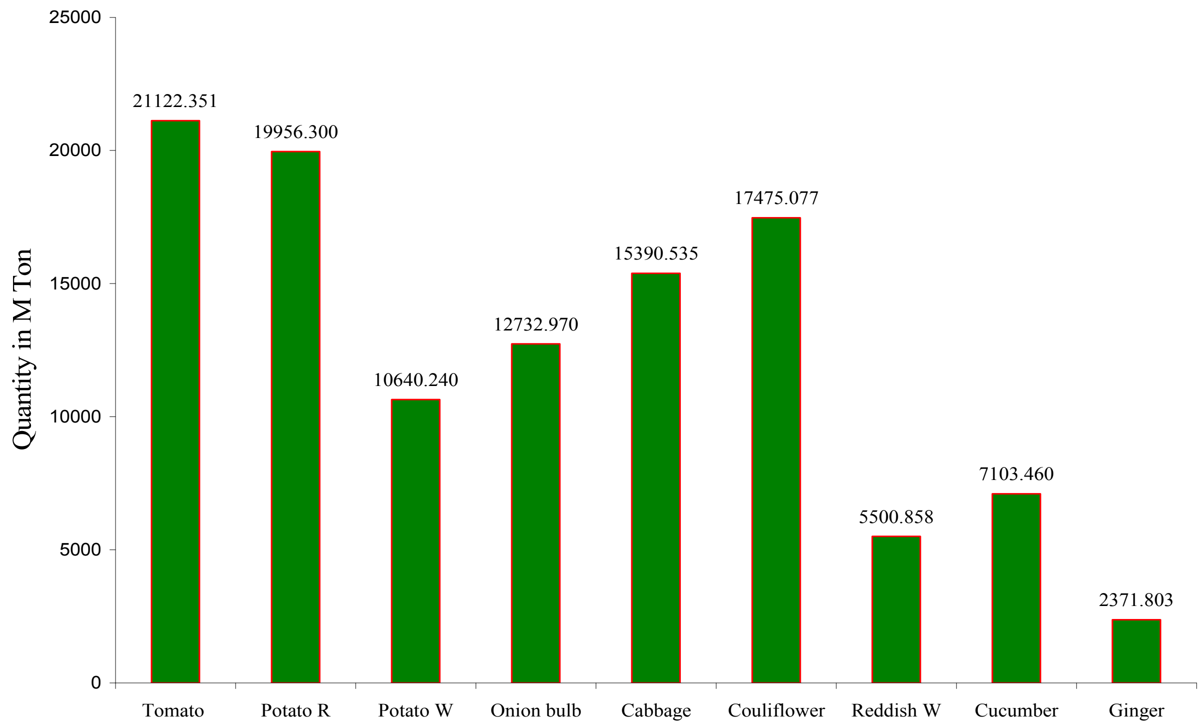


Figure: 5.12 Species wise vegetable marketed in Kathmandu vegetable market.

Of total vegetable imported in the Kathmandu Valley, Potato, including both red and white potato, occupies top position with more than 30000Mton. Tomato occupies second position with 21122Mton and cauliflower occupies third position. Similarly cabbage and onion occupies fourth and fifth position respectively. All above mentioned vegetable species are suitably grown in Kathmandu valley.

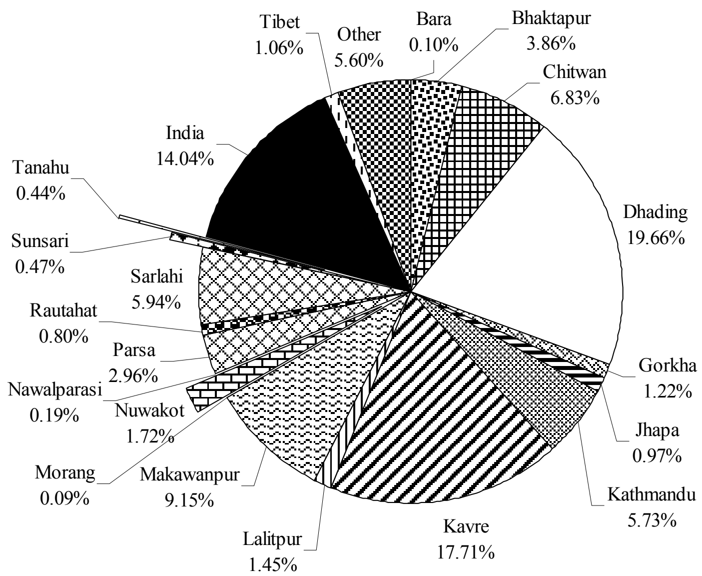


Figure: 5.13. Sources of the vegetable import in main market of valley

Kathmandu valley is one of the attractive markets for the vegetable growers in the neighboring district dwellers. Figure 5.13 gives an indication of vegetable imported to the valley from different source district, besides this about 15% contribution come from the India. In the same way contribution of the China (Tibet) is about 1.6%. All sorts of fresh vegetable come from India where as only dried vegetable is imported from the China.

5.7 Demography and socio-economy

Kathmandu valley being capital city, all the opportunities and economy is concentrated. Besides this since emergence of Maoist insurgency in the country, many people get migrated to the valley due to sense of security. Therefore, whole socio-economic and population trend has changed drastically.

5.7.1 Demography

The Kathmandu Valley has witnessed rapid population growth in urban areas and adjoining Village Development Committees (VDC). During the past 20 years, there has been a phenomenal rate of growth in the Kathmandu valley's population with significant role of in-migration. According to the census of 1920 (although not a scientifically conducted census) the total population of the Kathmandu valley was 306,909. The1950s marked a turning point in Nepal's demographic and political history. The first scientific census was undertaken during 1952/54, in two phases. According to this census there was a total population of 410,955 in the valley, of which 52.2% were rural residents. The size of the population in the valley has gone up from 0.41 million in 1952/54 to 1.1 million in 1991 (table as shown).

The growth rate between 1981 and 1991 is alarmingly high. The average annual growth rate for the three districts of valley is 3.7% with 5.1% in the urban areas and 2.3% in the rural areas while the growth rate of the Kathmandu Valley during the same period was 3.83%. If this rate continues unabated, the total population of the valley districts will double in less than 19 years. Among the three districts, Kathmandu had the highest annual growth rate of 4.81%, Lalitpur 3.81% and Bhaktapur 0.8% between 1981 and 1991.

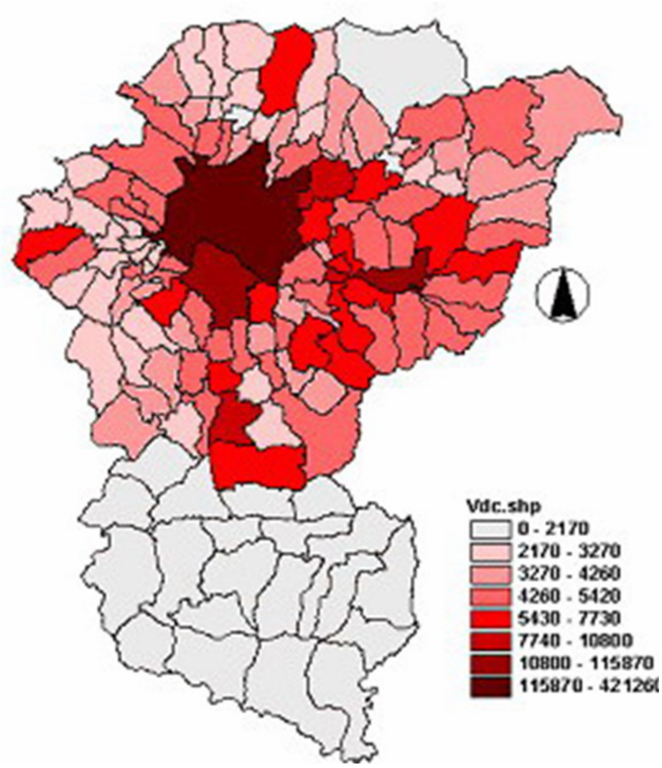


Figure: 5.14 Map of population distribution in study area

The growth rate of the urban population is higher than the rural population. The intercensal growth rate of the rural population was much higher during 1961 – 1971 and lower for the period 1971 – 1981. It is probable that most of the permanent migrants to the valley districts prior to 1971, lived in the rural settlements close to urban localities. In later years more people began to concentrate in the urban areas, contributing to the rapid growth of the urban population. The accelerated growth of the urban population after 1971 is further reinforced as the adjoining rural areas were amalgamated into the municipal areas.

Table: 5.10 Distribution of population by districts of Kathmandu valley, 1991-2001

District	1991	% of total population	2001	% of total population	Annual growth rate
Lalitpur	257,086	1.39	337,785	1.46	2.73
Bhaktapur	172,95	0.94	225,461	0.97	2.65
Kathmandu	675,341	3.65	1,081,845	4.67	4.71
KVD*	1,105,37 9	5.98	1,645,091	7.10	4.06

Source: CBS 2003

** Kathmandu valley districts*

Population growth of the valley

First population census was carried out in 1952 official figures of that census showed the population of urban area of Kathmandu Valley (KV) was 196,777, which is less than half the urban population of whole Nepal. Due to the development trend and migration towards the urban centers causes the urban population of KV increases to 995,966 against 2,227,879 people living in urban areas of whole Nepal.

Table: 5.11 Population density (per sq. km) from 1971 to 2001

Location	Year			
	1971	**1981**	**1991**	**2001**
Kathmandu	646.71	1068.95	1709.72	2738.85
Lalitpur	392.89	478.81	667.76	877.36
Bhaktapur	830.68	1342.58	1453.38	1894.63
Kathmandu Valley	**623**	**963**	**1277**	**1837**
Nepal	79	102	126	157

Level of urbanization is 60% in Kathmandu and that of the whole Nepal is accounts only 13.9%.

5.7.2 Socio-economic condition

Human development

The Human Development Index (HDI) provides a composite measure of three dimensions of human development: living a long and healthy life, being educated and having a decent standard of living. The HDI for Nepal is 0.534 (Appendix table 5). The UNDP Human Development Report (2004) indicates that Nepal is ranked 140th in HDI. It belongs to the category of low human development countries. However, it has been steadily increasing since 1975.

ICIMOD *et al* (2003) report that Kathmandu district is ranked first in the overall composite index of National development; the other two districts of Kathmandu Valley, Bhaktapur and Lalitpur rank 4 and 5 respectively (Appendix table 6).

Lalitpur district has a larger population and area than Bhaktapur. But the distribution of the per capita development budget is higher in Bhaktapur district. It also shows that Kathmandu has higher non-agricultural occupation than other districts in the Valley. The income gap spurs migration into the Kathmandu Valley. This survey has also identified that 44% of the poor live in rural areas, compared to 23% in the urban area (UNDP, 2004).

Poverty

The Human Poverty Index for developing countries (HPI-1), focuses on the proportion of people below a threshold level in the same dimensions of human development as the human development index - living a long and healthy life, having access to education, and a decent standard of living. The HPI-1 value of 38.1 for Nepal, ranks 84th among 108 developing countries. All three districts are placed in the higher level of the National poverty and deprivation index. Among these districts, Kathmandu ranks first, Bhaktapur second and Lalitpur third. 25 years ago, then Nepal's economy was predominantly agricultural. Still, the agricultural sector has more than 36% in the GDP, while the non-agricultural sector has 63% at the national level. Population migration also had a major effect on the economically active population rate in the Valley. In 1991, almost 15% of the total urban populations were migrants.

Employment Opportunities

Table: 5.12 Distribution of Population by Industry in 1995-96

Industry	% of Population
Agriculture	14.8
Mining	0.1
Manufacturing and Processing	21.9
Electricity, water and sanitation	1.2
Trade/commerce and related services	20.8
Construction	4.4
Transport and communication	5.5
General Labours (not specified)	4.4
Services (other than commercial)	26.9

Source: Nepal Rastra Bank, 1999

Most of the economic activity in the country is centered in Kathmandu Valley. Table 5.12 shows that more than 20% of the economically active population is engaged in the services sector. Only about 15% is engaged in agriculture compared to 80% at the national level.

Income and Expenditure

Nepal Rastra Bank (NRB, 1999) reports that an average per capita income of Kathmandu valley urban area is more than NRs 24,000 (US $ 343). Higher per capita income in the Kathmandu valley is in administrative and managerial work. Farmers also have a good income compared to other groups but higher family members in a household reduce purchasing capacity. Marginal farm households are operational agricultural landholdings (work themselves on farm as owner or tenant) having farm size of 0.5ha or less.

The major food production in each district is converted into kilocalories per capita per day and used as an indicator of the availability of food. Major food production is taken as the total production of rice, maize, wheat, millet, barley and potatoes. In this regard, Bhaktapur district produces more food. It is because larger proportion of Bhaktapur's population is involved in farming activities.

Table: 5.13 Food productions in KV

Indicator	Kathmandu	Lalitpur	Bhaktapur
Per capita food production (kilo calories)	2,263	2,385	4,267

Source: ICIMOD et al, 2003

Kathmandu district ranks first in total development facilities, but third in development facilities related to agriculture. All agricultural facilities are high in Lalitpur district, but it has poor irrigation facility compared to Bhaktapur. Bhaktapur produces surplus food, which it sells to the city area of the Valley. Bhaktapur's per capita food production is at 4,267 kilo-calories, which is higher than the other two districts (Table: 5.13). Lalitpur district comes third in total infrastructural development. This is because all 20 VDCs (68% of land) of Lalitpur district are situated in the hilly area of Mahabharat Range; only 32 per cent of the district's area is situated inside the Valley, causes to place it at lowest overall development rank.

As we descend from periphery of valley to the central followings changes are evident.

a. Cost of land per unit area is higher, which has influence on R/C ration. This used to be inspirational factor for conversion of agricultural land into non-agricultural and use.
b. Increase number of construction on agricultural land area. Number of holding adopting vegetable cultivation is reduced.
c. Decrease in agricultural labour availability, because high turn over rate of off farm employment.
d. Increase in rate of land fragmentation and decrease in area per land holdings this situation results into high input cost for cultivation.
e. Increase in water scarcity for irrigation.

6 DATA ANALYSIS AND RESULTS

Present chapters have been concerned primarily with the land and key soil properties, soil classification soil qualities & characteristics of soil found in the study area. It aims to identify current status of land use, land management and changes in land use form. In addition, this Chapter briefly lights on main land utilization types and cropping systems, and makes description on the production situation of the vegetables crops. Results obtained will be relates to multi-criteria land suitability evaluation in following chapters.

6.1 Land use in Kathmandu valley

6.1.1 Land characteristics

Basic sources of soil data in the present study is Global and National Soils and Terrain Digital Databases (SOTER), Digital soils and Terrain of Nepal, Version one released in 2004. Greater soil types and sub types are inherited according to the designated land unit. The soil data related to spatial information and boundary are calculated with the scale of 1:50,000. Soil collection was done through random sampling methods and taken for the fertility test. Digital soil maps developed by the department of Survey, Government of Nepal are further combined with the soil data collected during the field visit. Necessary updating was done especially physical and chemical soil properties of the study area. Land form and terrain type has also selectively inherited from different data sources. All of soil classes, sub classes and their physical and chemical properties have certain degree of influences to the cultivation practices in the study area. Therefore, the land suitability evaluation for the selected different vegetables crops would have to judge primarily on the basis of the soil characteristics. This has been found in the study area about indigenous names of soil types and production potential which was normally used by farmers to denote land types and practices on it.

Kathmandu valley is one of the represented land mass of the middle mountain of Nepal. The features and land characteristics of the valley resembles the middle mountain are presented in a generalised form like land form with dominant soil type and slope level in the table 6.1.1. According to Land System Report 1986, the major soil types found are Psamments, Ustorthents, Ustifluvents, Fluvaquents, Ustochrepts, Haplustalfs, Typic, Rhodic, Udic, Lithic, Anthrophic and Haplumbrepts (LRMP, 1986). Typic, Rhodic, Udic and Anthropic are dominant.

Table: 6.1.1 General land and soil characteristics in the middle Mountain of the Nepal

Land System	Landform	Land Unit	Dominant Soils	Dominant Slopes	Dominant Texture
9	Alluvial plains and fans	9a River channel	Psamments, Ustorthents	<1^0	Fragmental Sandy
		9b alluvial plains	Ustifluvents, Fluvaquents, Ustochrepts	<1^0	Loamy / Bouldry
		9c Alluvial fans	Ustochrepts, Haplustolfs,	1-5^0	Loamy / Bouldry
10	Ancient Lake and River Terraces	10a non-dissected	Typic and Rhodic, Haplustalfs, Ustochrepts	0-5^0	Loamy
		10b dissected	Typic and Rhodic, Haplustalfs, Ustochrepts	0-5^0	Loamy
11	Moderately to steeply slopping mountainous terrain		Typic, Rhodic, Udic, Anthropic, Subgroups of Ustochrepts, Dystrochrepts, Haplumbrepts	<30^0	Loamy Skeletal
12	Steeply to very steeply sloping mountainous terrain		Lithic, Subgroups of 11 and Usatorthents	>30^0	Loamy Skeletal

Source: Land Resource Mapping Project, System Report, LRMP, 1986.

6.1.1.1 Soil Groups

Soils of the Kathmandu valley was classified according to soil classification methods from the FAO-UNESCO classification system. Soil has been categorised in the broad groups and sub groups. The valley area accounts for five major soil groups & seven sub soil units (table 6.1.2). Distribution pattern of the soil groups are associated with the physiography of the valley and they are redially distributed. Dystrochrept and Rhodustalf groups have two sub-groups each while, rests of all other are single.

First group of soil Dystrochrept Anthropic show its distribution in the northern periphery of the valley boundary. There are series of uplands which extends up the 2600m above sea level. Altogether 14 land units have this type of soil covering an area of 1733.27ha which accounts for 7.2% of total agricultural land are in the valley. From productivity point of view, these types of soil holds moderate amount of the soil nutrients and most of them are of residual type; therefore they are taken as moderately productive type.

Dystrochrept Aquic is another sub group of Dystrochrept soil group which is distributed more in the north west part of the valley in between hills. Only single land unit is represented by this soil type. 572.38ha of land with 2.4% of total agricultural area of the valley has been covered by this type. Cereal corps are cultivating in this type of land continuously.

Fluvaquent Aeric is one of the most recognized soil types for the cultivation in the valley. Flat land in the valley floor is covered with this type. Loamy textured soil is with recent pedogenetic history are accumulated. Alluvial plains of the valley are made up of this soil. This is of transported soil and is formed due to the deposition of the soils around the hills. In these areas rate of conversion into build up area is very high. Unfortunately majority of the urban settlements are encroaching fertile land. In an existing condition, 4250.7ha from 12 land units have these types of soil group. In total they occupy 18.1% of current agricultural land area of the valley.

A Rhodustalf soil group has two sub groups in Kathmandu valley namely Rhodustalf Anthropic Udic and Rhodustalf Scalpic. They cover an area of 2792.84ha and 5515.78ha respectively with percentile conversion accounts 11.9% and 23.5% respectively. This is the dominant soil types in the ancient lakes like in Kathmandu and river channels. Majority of the periurban area in the Kathmandu valley has Rhodic soil type, where extensive cultivation of paddy-wheat is done. This soil groups occur in between surrounding hills and alluvial plains. Few patches of Ustifluvent Aquic Anthropic soil groups are also present in scattered form within valley. Altogether it is 6.4% of agricultural land area which accounts 1503.61ha. Maize-Barley cultivation pattern are dominant in this type of soils. Coarse textured soil in moderately steep land posses this soil groups. This soil type is often found in the mountain terrain of the middle hills of Nepal.

Greater soil group found in Kathmandu is Ustochrept soil, there are two sub groups of this soil types namely Ustochrept Aquic and Ustochrept Paralithic. Paralithic sub group of soil is one of the dominant soil types in the northern to east northern upland of Kathmandu valley. Eastern part of Kathmandu district and Bhaktapur district posses this type of soil. This soil group covers largest area that account for 25.4% with an area of 5965ha of agricultural land area. However, soil texture category of skeletal loamy are dominant with mixture of gravel and residual soil proportions. Area occupied with this soil groups are moderately slope of less then 30 degree. So water retention capacity is drastically reduced and organic matter content is also low. Therefore soil quality in general is categorized as low.

Table: 6.1.2 Soil types in Kathmandu Valley

Soil Types	Count	Area (ha)	% of Ag land
Dystrochrept Anthropic	14	1733.24	7.4
Dystrochrept Aquic	1	572.37	2.4
Fluvaquent Aeric	12	4250.71	18.1
Rhodustalf Anthropic Udic	22	2792.84	11.9
Rhodustalf Scalpic	17	5515.78	23.5
Ustifluvent Aquic Anthropic	6	1503.63	6.4
Ustochrept Aquic	11	1102.75	4.7
Ustochrept Paralithic	2	5965.79	25.4
Total	85	23519.33	100

Map depicted for the soil classification according to FAO-UNESCO system, show eight soil groups present within small area of the valley (figure: 6.11). On this basis it can be concluded that variations in the soil types can be related in the variation and orientation in the land form and cultivation practices. Pattern of land use and cultivation implies that soil appears to be exhausted in terms of nutrients. To bring back soil into good quality require to increase the organic matter contents, therefore need of constant application of organic manure seems necessary.

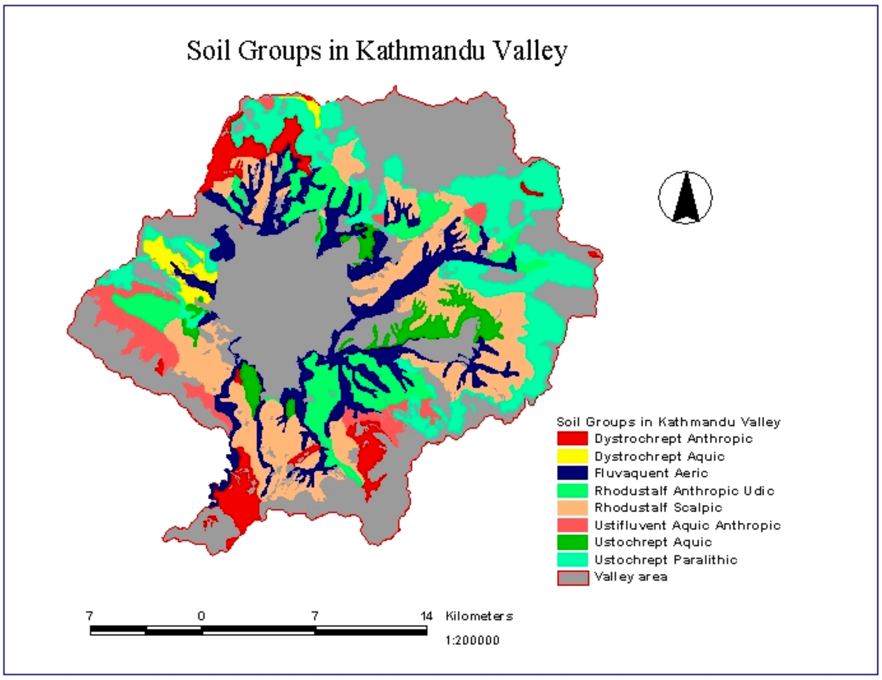


Figure: 6.1.1Greater soil types map of Kathmandu Valley

Moreover, topographic diversity has also contributed to some extent on diversity of soil group. Terrain type also causes soil loss, it can be mitigated but cannot completely be prevented. This fact has little been supported by the cultivation of the indigenous varieties of large number of vegetables within Kathmandu uplands.

6.1.1.2 Physical soil characteristics

Texture

Soil parameter to be studied has been categorised into physical characteristics and chemical characteristics. Soil texture means the relative proportion of the various size groups of individual soil particles. Texture provides important information regarding water holding capacity, permeability, irrigation requirement and erodibility. Growth and development of the plant primarily based on the soil texture. Root penetration, nutrition absorption through soil particles, water holding capacity, water infiltration and percolation are affected by texture type. Similarly, type of plant like tuber crop or leafy vegetables etc are well grown in specific soil texture class. There is little diversity found in terms of soil texture in Kathmandu valley. It possesses Loamy, loamy skeletal and loamy bouldery type of broad texture class.

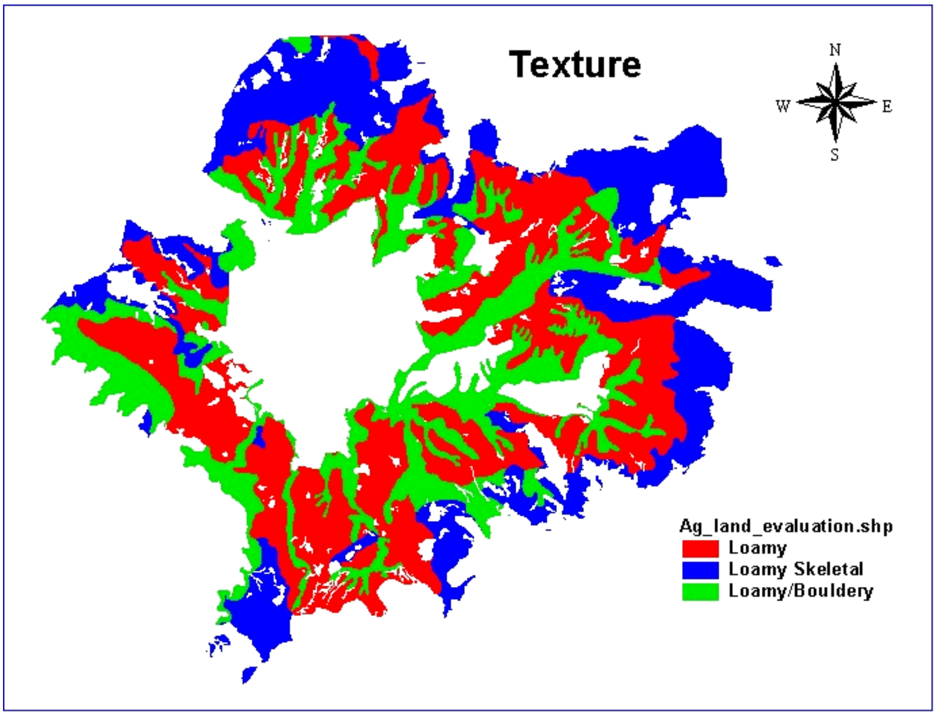


Figure: 6.1.2 Area covered by soil texture in Kathmandu valley

Soil test analysis reveals that loam, sandy loam, sandy bouldery, and silty loam are distributed in different land units. Loam and sandy loam are much more preferred soil type for the Kathmandu valley vegetable farming community which is one of the most suitable categories and accounts for 45% of the total existing agricultural land area of the valley. This figure is about 18% of total land mass of the Kathmandu valley. About 1% i.e. 260ha of agricultural land area has very rough texture and apparently not able to support any crop cultivation, this is catagorised into unsuitable on the basis of texture parameter (figure 6.1.2).

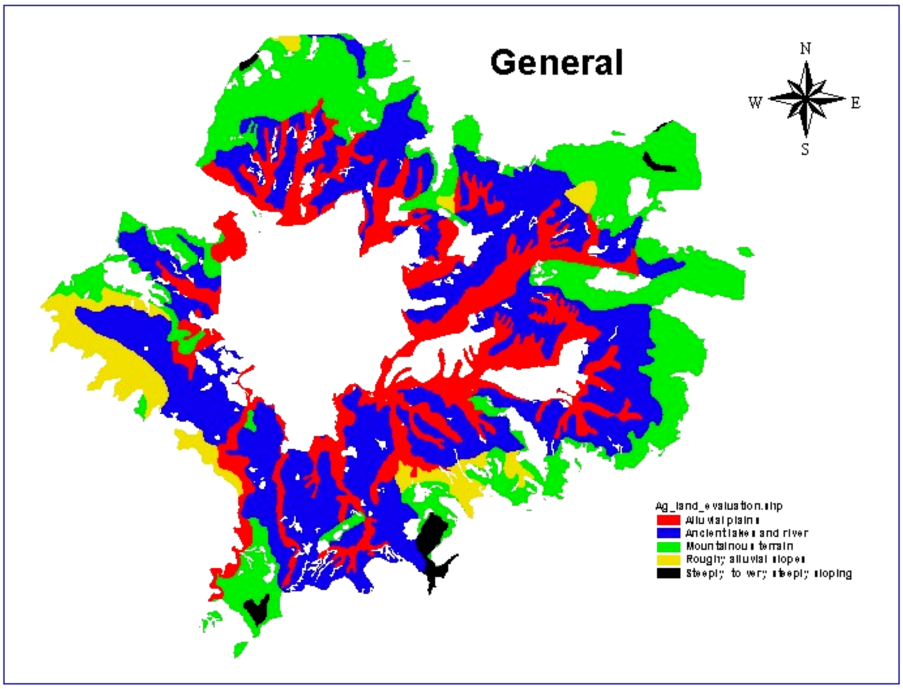


Figure: 6.1.3 General land form in Kathmandu Valley

The particularly, soils on the valley bottom are of alluvial type where as on the peripheral mountain range are skeletal ones. Majority of the land unit possess different form of loamy soil. Pedogenesis in the Kathmandu valley is not much old, recent history of pedogenesis has been attributed general types of land form as indicated in the SOTOR (2004) database. Area coverage of general land type is given in the table 6.1.3.

Table: 6.1.3 General land forms in Kathmandu Valley

SN	GENERAL Land Forms	Counts	Area (ha)
1	Alluvial plains and fans (depositional)	18	4948.45
2	Ancient lakes and river terraces (tars) (erosional)	45	9285.97
3	Moderately to steeply sloping mountainous terrain	12	7491.63
4	Roughy alluvial slopes	6	1503.61
5	Steeply to very steeply sloping mountainous terrain	4	289.62
	Total		23519.33

Top soil depth is for the cultivation is another important factor controlling cultivation methods as well as the selection of the crop type. Pedogenesis is very gradual process. Formation of the thick layer of soil can be achieved through transportation of soil particle from other area, and erosion activities in contrary causes diminishing soil thickness. Surrounding hills of Kathmandu shows relatively thin soil depth where as alluvial plain at the bottom shows very thick layer with more organic matter within. For good root penetration, sufficient soil depth is one of the pre requisites (figure 6.1.4 and table 6.1.4).

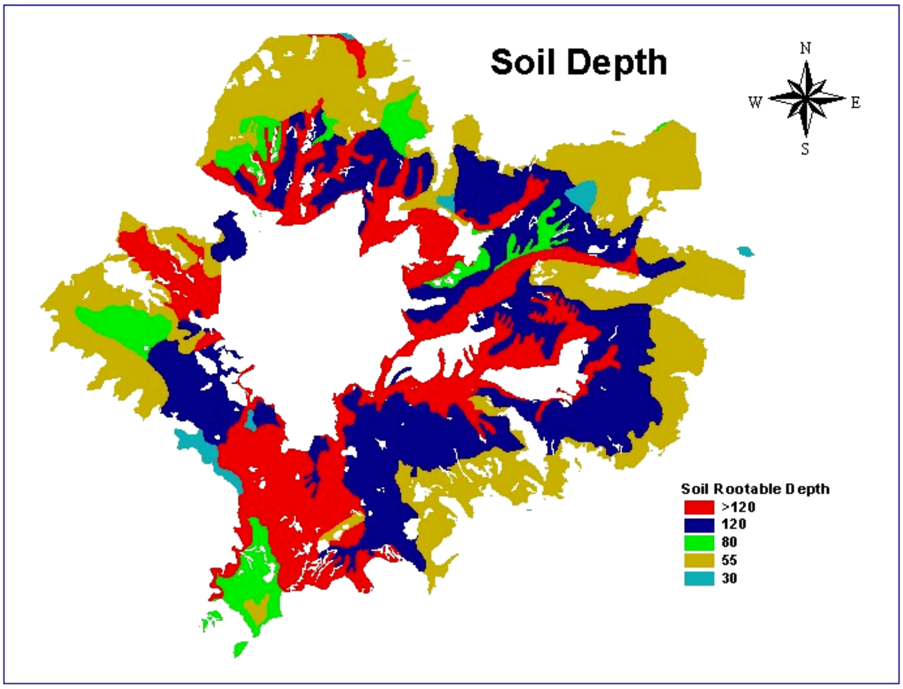


Figure: 6.1.4 Soil depth distribution in the valley

Table: 6.1.4 Soil depth distribution in study area

Soil Depth	Count	Area (ha)	Area (%)
>120	17	6106.08	25.96
100 - 120	38	6944.14	29.53
80 - 100	11	1742.99	7.41
55 - 80	12	8420.66	35.80
30 - 55	7	305.47	1.30
Total	85	23519.33	100

Study Result shows that about 45% of total agricultural areas have top soil depth more than 100cm depth (table 6.1.4). Especially for the vegetable cultivation, such a depth is sufficient and categorised to the most suitable soil depth category. Most of the hilly landscapes with sloppy topography have thin soil layers with lesser number of horizons.

6.1.1.3 Chemical soil characteristics

Soil fertility

Cultivation always aims for productivity. Production potential of the soil is based on the quality of the soil. More precisely, fertility of the soil is a key to the growth and development of the soil and productivity. The fertility of soil is a decisive factor for plant growth. And fertility is the factor cumulatively attributed by different chemical parameter. Most specifically Nitrogen, Phosphorus, Potassium, pH, and organic matter content are the key parameters. So these factors work together for the productivity decision of the vegetable crops. Fertility of the all 85 land units are given in the appendix. Moreover NPK used to get fluctuate within given period of time it is not taken as the permanent soil parameter. Therefore, external input can make necessary correction over soil fertility of any area. Nitrogen in soil is an important indicator reflecting biological condition and the nutrient status of soil. Microbes in soil change in to microbial protein. Nitrogen content of the soil averages about 0.14% with only 5% land area contains more than 0.2% total nitrogen. Similarly phosphorous is ranges from high to medium level.

Table: 6.1.5 Average fertility level of different soil group from study area

Soil Group	**pH**	**OM** %	**N** %	**P** Kg/ha	**K** Kg/ha	**WHC** %
Dystrochrept Anthropic	6.10	2.17	0.11	41.40	49.97	11
Dystrochrept Aquic	5.07	2.33	0.22	92.10	98.16	28
Fluvaquent Aeric	5.20	2.37	0.12	123.40	68.04	16
Rhodustalf Anthropic Udic	6.60	2.23	0.16	171.42	210.30	15
Rhodustalf Scalpic	6.00	1.32	0.07	33.20	278.88	23
Ustifluvent Aquic Anthropic	5.40	2.45	0.12	173.00	206.00	21
Ustochrept Aquic	4.90	2.90	0.15	155.70	282.70	12
Ustochrept Paralithic	5.90	4.22	0.13	395.00	381.00	12

Soil pH

Soil reaction is the degree of acidity or alkalinity of the soil and pH is the negative logarithm of the H ion activity. This refers to the relative activity of the H ion in the soil solution. In present investigation pH value ranges from 3.9 to 6.8. pH of given soil presents an indication of the degree of availability of many soil nutrients and the favourability of soil condition to microbial activity which contributes to the fertility in turn.

Organic matter

Organic matter content of the soil is an important parameter related to soil fertility. Further decomposition of organic matters by microbial activities yields humus. These are true nutrient to the plant available in soil. Good humus content in soil improves infiltration rate and water holding capacity. The high amount of soil nutrients such as nitrogen (over 90%) and phosphorous are in organic form which become available to plants upon mineralization. Organic matter contributes much to the cation exchange capacity (CEC) of soils and plays a major role in retaining potassium, calcium, magnesium etc. Organic matter is ranging from 0.12% to 7.8%. This value is not the appreciably high. This indicates that constant application of the organic matter in the soil is not appropriately done. In long run, lack of sufficient organic matter may cause several soil complications like decrease in productivity to soil erosion.

Water holding capacity (WHC)

Water holding capacity is the amount of water taken by unit weight of dry soil when immersed in water. Water holding capacity gives an indication of the ability of the soil to provide moisture over a non irrigated drought period. This capacity related to soil texture and soil organic matter. Sand possesses low WHC, while silt, clay and soil rich in organic matter have high values. Present investigation shows water holding capacity ranges from 28% in Dystrochrept Aquic soil type to 11% in case of Dystrochrept Anthropic. There is fluctuation in the value of WHC even in all the sample plots within same land units.

6.1.1.4 Land characteristics

Slope gradient

As we ascend from alluvial plain towards the rocky, rough sloping mountain terrain, the top soil depth decreases accordingly. In the hilly steep area rate of soil formation is very slow and soil runoff due to rainfall is high. It is also evident from the slope map of study area, more than half (60%) of the agriculturally significance land area posses gentle sloping ranging from 0 to 5° slopping topography.

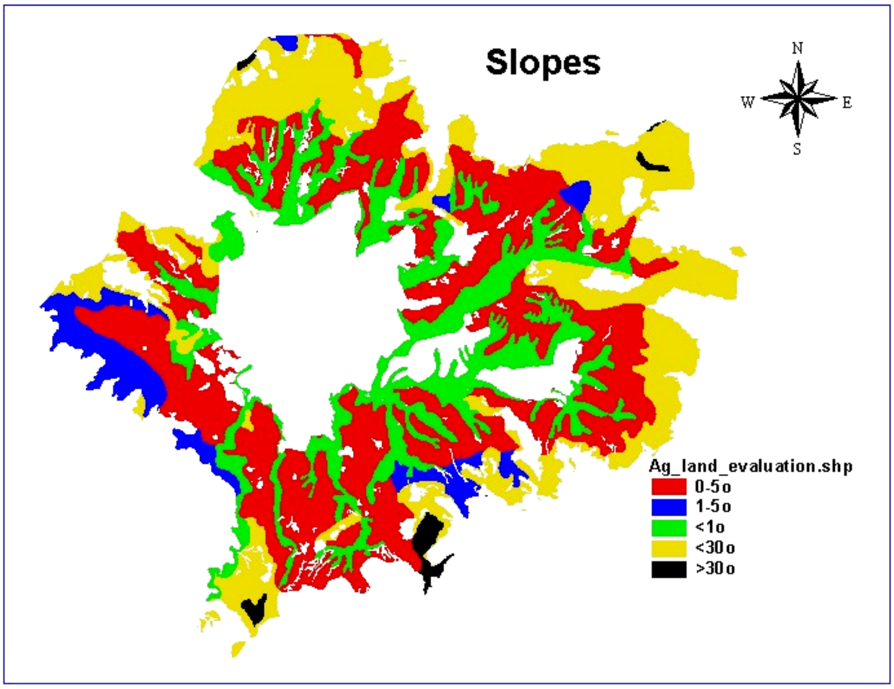


Figure: 6.1.5 Land slope map of Kathmandu valley

Traditionally, in the study area agriculturally practices are done making terrace, however in the rainfeed uplands, cultivation in the sloppy areas still in practice. Due to complex land structural slopping land has been categorised into flat, gentle slop, slightly slop, highly slop and steep slop. Agricultural practice in the steep slop is regarded as highly unsustainable agricultural practices. With appropriate technology, cultivation in the slope up to 30° can have satisfactory production.

Aspect

Sun shine duration to the agricultural crop is one of the important physiological needs. Long-day, short-day and day neutral plant can be selected for the cultivation according the suitable day light duration. Since Kathmandu is much hilly with crisscross topography all areas are not equally illuminated all the days of year. According to the sunshine hour data, on summer sun shines for 14 hours and 10 hours on winter days however real sunshine hour for particular are differs. This has affected by the terrain, so aspect is one of the important attributes to be consider for the suitability assessment. Land units of Kathmandu valley cannot be generalised. Aspect must be considered during land selection procedure. Majority of the vegetables on north and north-east facing slop couldn't contribute for the appropriate growth. In the study area existing agricultural land are categorised into three different aspect categories (table 6.1.6). First category includes flat land to east to south facing slope, second category is land facing towards south, north and south-west where plant grow well. Finally last category includes land facing west and west-north direction. On degree of suitability, category I is the best and category III is holding low importance. This aspect map was derived from the Digital Elevation Model developed from the contour map of 20m contour line.

Table: 6.1.6 Orientation of Agricultural Land

ASPECT	Direction	AREA (ha)	%
Aspect I	Flat, E, N-E, E-S	23278.68	65.1
Aspect II	S, S-W, N	5875.65	16.5
Aspect III	W, W-N	6607.98	18.5
		35762.31	

Study area shows degree of limitation to restrict growth and development of vegetable crops homogenously. Limitations degrade the land capability to support the vegetation, so suitability evaluation will be effected. A general climatic limitation is the inadequate climatic factors for the optimal growth of the specified crops. Temperature indicates inadequate heat unit, moisture indicates inadequate moisture and precipitation relates to insufficient or excess rainfall in an area. Similarly, a general soil restriction includes water holding capacity/texture which indicates land area where the specified crops are adversely affected by lack of water due to inherent soil characteristics. Soil structure limitation adversely affects the plant growth by soil structure that limits the depth of rooting, or by surface crusting that limits the emergence of shoots. Such a restriction can be seen in organic matter, depth of topsoil soil reaction and drainage. Similarly, general landscape restriction is the slope limitation, landscape pattern, altitude and aspect (Pettapiece 1995). The suitability evaluation will help on identification of the limitation so that appropriate soil and land management approaches can be applied. Hence production potential of the land can be enhanced.

Discussion

Soil parameters of the investigated are reveals that soil quality can support wide range of cultivation. Most land surface has gentle slope cultivated making terrace. Irrigation facilities are not enough in all cases. In many areas it has to depend upon rainfall. Top cultivable soil depth is enough for the root depth. Organic matter content in soil is moderate, the higher value is found in the agricultural area near the natural vegetation or forest stands. Total fertility is low to moderate in valley soil. Fertility of the soil is more about temporary matter and can easily be enhanced by external application of fertilizers. Nitrogen, phosphorus and potassium fluctuation are usually maintained through external application. Integrated plant nutrient management (IPNM) is an important component for the sustainable agriculture intensification in an area like Kathmandu valley. It includes technologies like soil conservation, nitrogen fixation and organic and inorganic fertilizer application (Gruhn et.al. 1995). Lower the elevation, higher the clay content in the soil is observed. More then 70% area is loamy soil of different category that is good enough to support plant growth. Water holding capacity coincides with the textural properties of soil; it is optimal for the growth and development of vegetable crops. Moderate diversity of soil group in valley related with the variation in soil parameters. Strength and limitation of the soil parameters help making decision on soil improvement activities to enhance production potential of land.

6.1.2 *Changes in land use and land use categories pattern*

6.1.2.1 Land use categories

The urbanization of the valley started in the late 1950s, since 1970s urban growth has been rapid and unplanned. Land use in greater Kathmandu has changed dramatically in the last two decades. In greater Kathmandu, the urban area has expanded from 24% of the total area in 1971 to 67% in 1991 at the expense of prime agricultural land. It is estimated that urban areas have increased by 7% of the total valley surface area between 1984 and 1990 and prime agricultural and has declined from 63% to 56% (Harcrow Fox and Associates, 1991). Now the urban areas are expanding at an annual rate of 4.4% (Karki, 1991). It is estimated that more than half of the valley's top class agricultural land is under the threat of urban sprawl. Agricultural land occupies 40% of the total area. Combination of level terraces, irrigated tars and sloping terraces form the agricultural lands. Similarly forest in the peripheral area of valley and shrub land together occupies forested land category that cumulatively occupies almost 24% land area. Shrinkage of the forested land area is not much evident then other category. Soil clefts, sand bed in the riverbanks are also accounting some less than 1% of land area. Forests and shrubs occupy 25%. Plantations has been carried out since long time, this also makes the balance between degradation of existing forest and development of forest in the marginal area, bringing almost to balance state. While urban and industrial areas occupy 33% of the valley. The reported area ranges from 596 to 760km^2. (HMG/ IUCN, 1995). In this study, the area of the Kathmandu Valley is calculated from a topographic map on a scale of 1:50,000; the area is 583km^2. Kathmandu Valley is at a mean elevation of 1,350 meters above sea level. The land use analysis of the Kathmandu valley region is intended to provide for an understanding of status of the ecological conditions both natural and man-made. In Lalitpur district establishment of stone quarries and brick industries are also in expense of the agricultural lands.

Current land use, particularly in the urban areas, is unregulated and unscientific (table 6.1.7). Such unplanned growth is not only prevalent in urban areas but also in rural areas such as hilly site like Nagarkot, where tourism infrastructure and facilities are developing at entrepreneur’s will, without any consideration for proper use of land based on its capabilities. Soil is the major treasure of the land, qualities of the soil has not been considered while making decision regarding its use. There has not been any defined strategy and guidelines to develop the valley as an industrial and commercial centre or as a cultural, tourist, administrative and political capital. Consequently, the valley has developed with mixed features of industry, tourism, education and administration. Spatial representation of current land use is presented in figure 6.1.6. The uncertainty about the Kathmandu valley's feature is of great concern to urban planners.

Table: 6.1.7 Land use category in Kathmandu valley

Land use category	Area (ha)	% of valley area
Agriculture	23519.3	40.3
Built-up	19484.4	33.3
Forest	10847.7	18.6
Open field	413.9	0.7
Shrub land	3688.4	6.3
Water body	416.1	0.71
Total	58369.9	

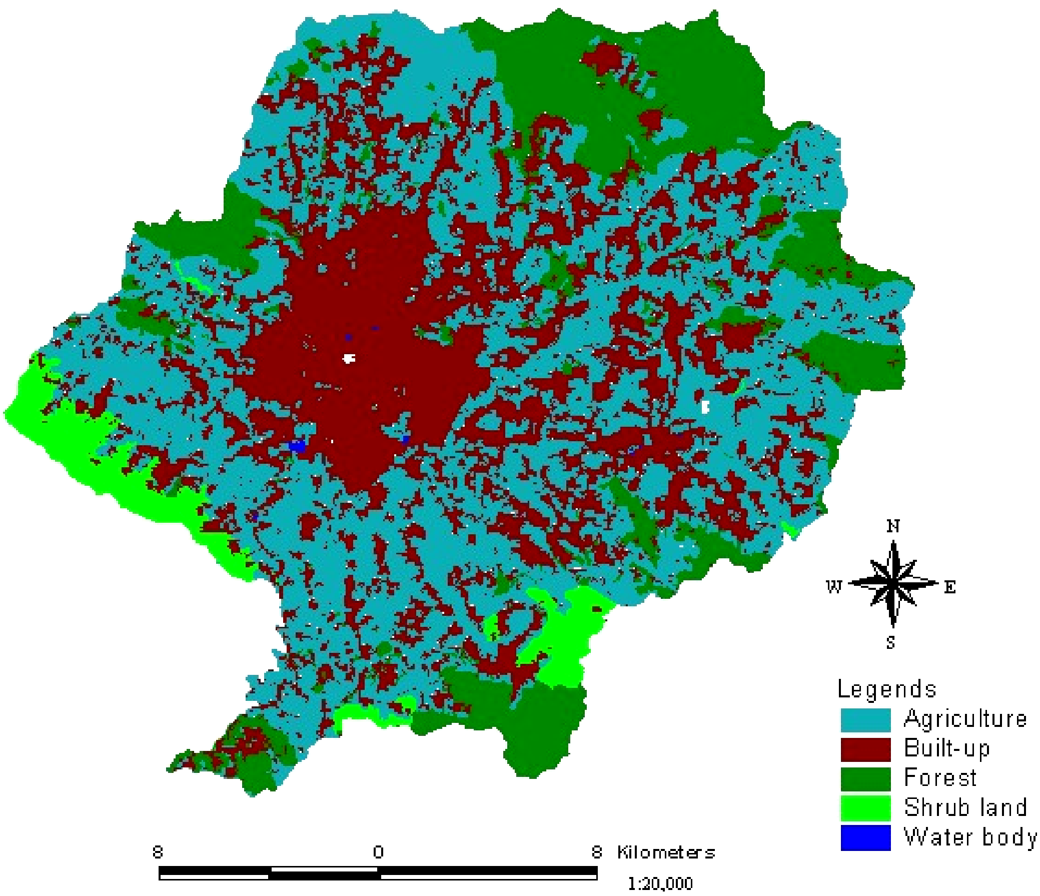


Figure: 6.1.6 Land Use Category in Kathmandu Valley, with valley boundary

6.1.2.2 Changes in Land use Pattern

Agricultural land dominated the Kathmandu Valley over 35 years ago. However, it has been converted to various uses like building construction, industrial establishment, governmental premises, etc. GIS analysis shows that 7% (2,848ha), 6% (1,962ha) and 26% (8,765ha) of agricultural land has been converted for non-agricultural purposes from 1955 to 1978, 1978 to 1991 and 1991 to 2000 respectively. Similarly 4.6% agricultural land had converted in the period of 2000 to 2005. The largest conversion occurred between 1991 and 2000 (IUCN, 2001). It is estimated that more than half of the valley's 'A' grade land will be lost to urban sprawl by 2010 if present trend of urbanization continue without any control measures imposed by policy making body (MoPE 2003). The agricultural land use of three districts in Kathmandu Valley was also studied to pinpoint the location of change. The agricultural land use change of three districts is shown in figure 6.1.7.

Therefore district wise statistics shows that 10%, 8% and 24% of agricultural land has been converted from 1955 to 1978, 1978 to 1991 and 1991 to 2000 respectively in Kathmandu district. In Lalitpur District, 5%, 6% and 20% of agricultural land has been converted from 1955 to 1978, 1978 to 1991 and 1991 to 2000, respectively. Similarly, 5%, 1% and 36%of agricultural land has been converted from 1955 to 1978, 1978 to 1991 and 1991 to 2000 respectively in Bhaktapur district (figure 6.1.7). This shows that while the lowest rate of conversion happened in Bhaktapur district from 1778 to 1991, the highest rate of conversion also happened in the same district from 1991 to 2000. This phenomenon can be attributed to the value of land, which is cheaper in Bhaktapur district compared to the other two districts (CBS, 2002, i.e. Sample Agriculture Census 2001)

The agricultural land use of three districts in Kathmandu Valley was affected by urban sprawl within this period. Most affected district is Kathmandu while Lalitpur and Bhaktapur are comparatively less affected. Because of the cheaper price of an agricultural land in Bhaktapur, more land area in recent days has been going under conversion to non-agricultural purpose.

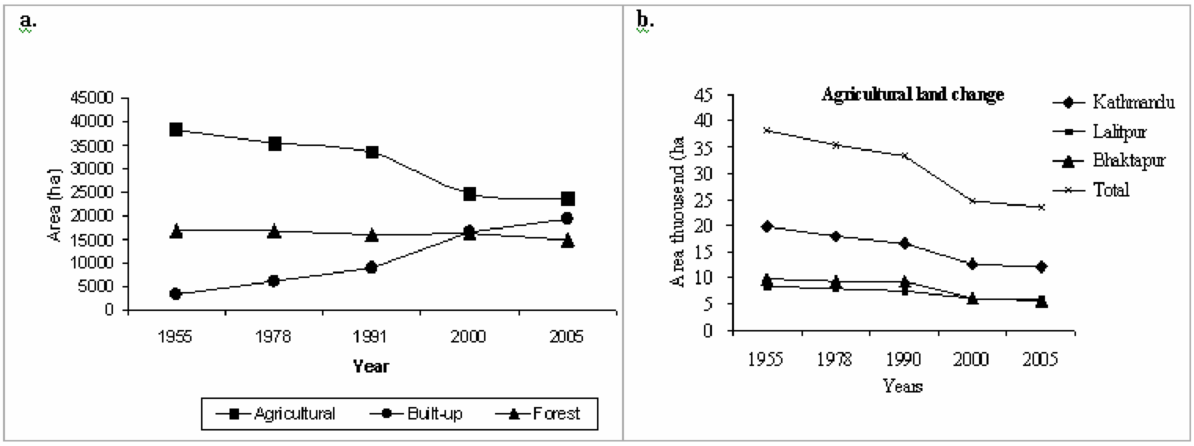


Figure: 6.1.7 (a and b) Land use change in Kathmandu Valley

Unfortunately, Bhaktapur district has large number of small poor farmers compared to other districts. Land developers bought large tracts of agricultural land in the peri-urban area, and divided them into smaller plots of different sizes and shapes for building construction. This is found to be peak stage of land fragmentation (figure 6.1.6). One of the main reasons of conversion of agricultural land to non-agricultural land is the rising market prices for land.

Table: 6.1.8 Land use changes in Kathmandu valley in different course of time

Land Use	1955	1978	1991	2000	2005
Agricultural	38,226	35,378	33,416	24,651	23,519
Built-up	3,330	6,152	8,917	16,472	19,484
Forest	16,810	16,831	16,028	16,350	14,948
Recreational				416	
Water body				473	416

Built-up Area

Figure: 6.1.8 Expansion of unplanned settlements in agriculturally active land

GIS analysis shows that the built-up area has expanded from 3,330ha in 1955 to 6,152ha in 1778, to 8,917ha in 1991 and further to 16,472ha in 2000 and 19484ha in 2005 (table 6.1.8).

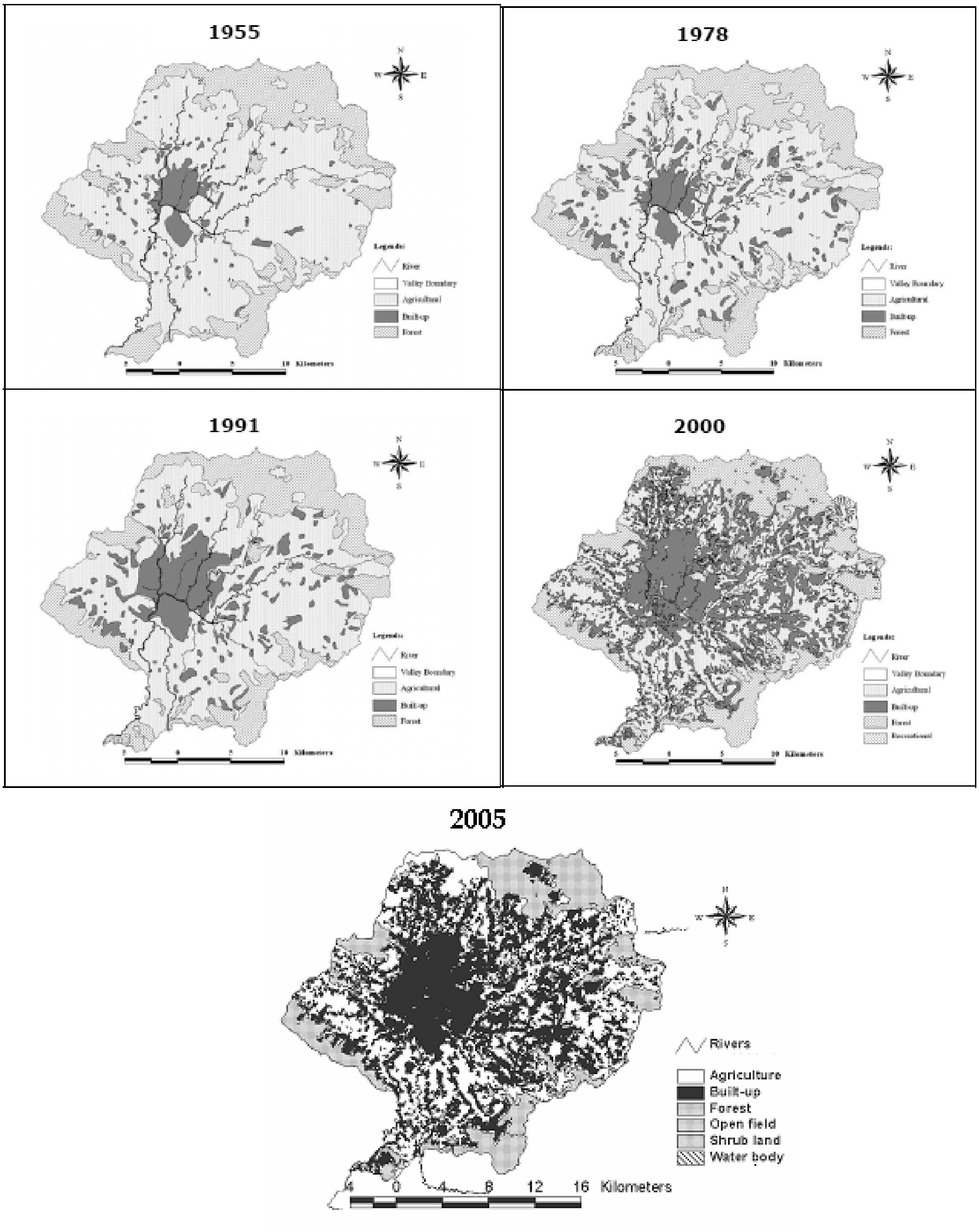


Figure: 6.1.9 Land use Change in Kathmandu Valley (in chronological Order)

During the period of half a century (from 1955 to 2005), the built-up area has expanded six-fold. A district-wise analysis revealed that the built-up area was much larger in Kathmandu district compared to other districts. Population increase is one of the main causes of the urban sprawl in the valley. In migration for the facility and security are the driving factors of the migration.

In general, GIS analysis shows that agriculture land is shrinking, forestland is stable and built-up area is increasing in the Kathmandu Valley (figure 6.1.9). Uncontrolled and unplanned growth has had a negative impact on the whole community, especially in agricultural land use, such as deterioration of quality of agricultural land, shortage of labour and domestic water, problem of solid waster management, etc. Expansion of built up area is inevitable but well planned settlements can mitigate the related consequences.

6.1.3 Agricultural practices in Kathmandu valley

6.1.3.1 Agricultural land holding

It also accommodated the largest and most rapidly growth urban population and economy in the country. Valley's urban activities are taking place on flat valley bottom that is rapidly replacing agricultural land. Average land holding size of the Kathmandu Valley is 0.263ha (CBS, 2003). Land holding size in three districts of the valley, Kathmandu, Lalitpur and Bhakapur are 0.25ha, 0.31ha and 0.23ha respectively. These values are quite smaller against average land holding size against whole Nepal which is 0.80ha further this value for hilly region of Nepal is 0.66ha and for the central development region is 0.73ha (CBS, 2006). At the present stage of development, converting agricultural land to urban settlements appears to be economically and socially lucrative. The high land prices on the urban fringe certainly indicate that the rate of return and net benefits of converting agricultural land to urban uses is encouraging. Yet the potential benefits of converting agricultural land to urban use conceal other costs, including those caused by pollution, congestion, loss of green space rising costs for urban management, services and agricultural products. If the present trend of urbanization continues, all prime agricultural land in the valley, except in the hills (i.e. about 15%) will be converted into urban area by the year 2020. This would invariably lead to an increasing encroachment on forest land for cultivation and for other purposes. The riverine ecosystem is undergoing rapid degradation, as rivers become a major depository for urban wastes.

National sample census of Agriculture 2001/02 shows the average area under cultivation in Kathmandu district 13,285.4ha which has been divided into 129,897 parcels. 26354 holding are getting different form of irrigation this altogether covers up the area of 5,004.1ha. Still there are 27270 holdings are deprived of any form of irrigation sources.

Table: 6.1.9 Agricultural land area in Kathmandu valley districts

Description	**Kathmandu**	**Lalitpur**	**Bhaktpur**
Total Agricultural area (ha)	13285.4	9958.6	6000.1
Total number of parcel	129,897	89825	86773
Area of land with own Ownership, ha	9839	8693.1	3422.4
Area under temporary crops ha	12,718.4	9305.1	5517.6
Area under Irrigation ha	5004.1	2824.0	2588.1
Area of vegetable cultivation ha	1200.5	413.8	458.0
Area under tuber crops	1005.8	190.8	354.1
Area cultivation of Spices ha	93.9	63.9	49.7
Area of winter potato	929.2	105.2	326.8
Summer potato	37.5	57.2	26.9
Area of cardamom ha	5.6	2.0	0.0
Winter vegetables	960.5	260.6	347.0
Simmer vegetables	240	153.1	111.1
Total Land area (sq km)	395	385	119

Source: CBS (2002)

In Kathmandu district, out of 13285 hectare of agricultural land, 329.2 hectare of land area made uncultivable due to flood or soil erosion. This area comprises 4660 number of agricultural holdings. Sample agricultural Census, 2001/02 has indicated area with different soil type of the valley districts on the basis of the response from the farmers is presented in table 6.1.9.

Major issues and problems of land use in Kathmandu Valley

Prime agricultural land is rapidly being converted for urban use, and increasing demand for fuel wood, fodder and timber in the surrounding hills has resulted in massive conversion of forest land into scattered forests, shrub land and grassland. The major land issues facing the Kathmandu valley are a) Lack of a comprehensive land use policy base on the land capability, b) Sustainability of both agricultural and forest land in the valley has been threatened and c) Declining forest biomass and loss of soil fertility.

The basic objective related to urban development of Kathmandu valley was set out to promote urban development & play supportive role in economic development. It is also aiming to establish urban-rural friendly relation. During the last two to three decades, the transportation network has increased in the urban areas. The road network in Kathmandu is composed of radial roads extending out from the core area of Kathmandu and functioning as arterial roads in the valley which works as the frame work for the housing development and expansion of settlements (table 6.1.10).

Table: 6.1.10 Interventions and their Impact of on the Kathmandu valley

Intervention	**Impact**
1. Urban uses & Manufacturing industries	Loss of prime agricultural land, misuse of land Increased extraction of sand/gravel from riverbed Degradation of riverine ecology
2. Industry	
a. Quarrying	Loss of forest land and degradation of surrounding forest Loss of agricultural productivity in the downstream areas
b. Brick-making industry	Loss of Prime agriculture land Loss of mineral rich topsoil, loss of agricultural productivity
c. Extraction of sand/gravel from the riverbed	Loss of riverine features such as riverbanks Deepening and narrowing of river channels Biological threat to aquatic life and physical threat to existing bridges

Growing household number and increasing economic activities in the valley demands much energy in the form of electricity, petrol, diesel, gas and kerosene. Increasing demand for electrical energy coupled with limited supply has in fact forced to use fuel wood as the main source of energy in rural household. There is ever increasing demand of the electricity in the valley with is presently 10%, but capacity has yet to be developed to meet the demand. Poorer sector of the society depends on cheaper modes of energy.

6.1.3.2 Horticultural practices

Kathmandu Valley was predominantly an agricultural area until the 1960s, and grew surplus crops and vegetables to feed people, shrinkage of the agricultural land caused difficult to support the people through production of crops and vegetables within the Valley. However, urban and peri-urban agriculture still plays a critical role in sustaining livelihoods in Kathmandu Valley. Close to 23% of the vegetables consumed in Kathmandu are produced by farmers in urban and peri-urban agricultures. This figure can be raised to 76% by improving farming practices and constructing a road networking system from the peri-urban to urban area and help to attain self-reliance in food and vegetables (Annonymus, 2001).

In Kathmandu valley two systems of vegetable production are in practice, namely at subsistence and at semi-commercial level. In the first system' most of the vegetables that are produced are utilized for domestic consumption, and it is estimated that about 84 percent of the farmers belong to this group. 16% of the farmers are semi-commercial and are producing for the market as well (Morris, 1990). Subsistence farmers generally grow vegetable crops in small areas, mostly mix-cropped with staple food crops. Traditional and indigenous knowledge and practices prevail. Little seed of improved varieties, or introduced practices and inputs are adopted, and a very small fraction of time or labour is devoted to vegetable farming. Production and productivity are both below the semi-commercial farming. In up lands hill farming, practices are related with the tribal culture.

Figure: 6.1.10 Periurban Horticultural Practices in Kathmandu Valley

The agricultural system of valleys has rapidly changed from indigenous knowledge-based integrated subsistence agriculture to more specialised monoculture practices. Introduction of new technologies, adaptation of high yielding varieties and commercialisation of agriculture contribute to such changes (Gautam, 2004).

Many factors have been identified causing poor productivity of vegetable crops under home gardening conditions. The technologies were not accepted by the resource poor hill farmers, because most of the technologies were developed for good management, high inputs, and ideal environment conditions. Performance is found very poor under various stress conditions, which are common in subsistence hill farming. Although many good local and wild varieties and appropriate local farmers' practices have been reported as being available and practiced in the hills of Nepal (Budathoki, 1992), very little attention was paid to collection, identification, evaluation, multiplication, extension, and training activities on these crops, varieties and practices. Another reason for failure is farmers' needs, problems, their socio-economic conditions, access to inputs, markets, and resources are rarely considered while planning and executing improvement programs.

A specialised core valley farming community is collectively known as '*Jyapoos*'. This community used to produces the greatest share of fresh vegetables for the Kathmandu market, and is known for its good practical skills and expertise in intensive traditional agriculture, especially for vegetable production (FAO 1994). Traditional methods included keeping and maintaining quality seeds, using local compost and organic manure are peculiar to Kathmandu farmers. Every bit of land is used efficiently. Black clay, compost, and human excrement were the traditional sources of manure. Similarly soil condition and crops status were also maintained by indigenous methods. But at present number of families devoted on the vegetable farming reduced drastically and traditional method has largely been replaced by new ways of cultivation.

6.1.3.3 Considerations of traditional vegetable farming

A. Indigenous technologies

Local varieties and practices may be of low productivity but their production is stable. They produce some yield, instead of complete failure and are not prone to diseases, pests, high or low moisture levels, high or low temperature, and poor soil fertility. They are suitable for local farming systems and practices, e.g. mixed cropping with staple crops.

B. Ethnicity

The geographically concentrated ethnic distribution pattern generally remained effect in way of cultivation and farming pattern. Place like Kathmandu valley, where upland area is still dominated by indigenous local people shows traditional pattern of farming. Conglomeration of ethnic tribe in any locality results cultivation practice to be increasingly dispersed. Lowland, flat area of Kathmandu basin is inhabited mostly by *Newars*. They historically have been the prime agents of Nepalese culture and art. Cultivation is still adopted by significant number of them also were engaged in farming. In that sense, they can be described as agro-commercialists. Existing farming pattern carries a lot of traditional practices developed by *Newar* of Kathmandu.

C. Labour system

Farmers could cultivate land intensively using the family labour force and labour exchanged within the community, which enabled them to secure produces with little direct financial cost. The labour exchange system is a social capital still widely found in subsistence economies and popularly known as “Parma System”. But the system is slowly deteriorating because there is less number of families fully dependent on agricultural system. This trend of involving off farm employment is particularly seen in the younger generation. As a response to this problem, horticulture practice has been slowly shifting towards crops that require less labour, such as fruit plantations. However, due to the ever increasing rural–urban migration in pursuit of better income opportunities, small farmers increasingly face labour problems (FAO and UNDP 2003).

D. Agricultural equipment

Mechanisation of agriculture in Kathmandu valley is very rudimentary and at low level. Majority of the holdings using the most common hand drawn agricultural equipment, the trend is increasing in last census. The use of tractors is uncommon due to the topographic constrains. Use of the tractor and heavy machines in Terai belt had higher incident compared to other parts. Its use is limited in hills and mountain regions due to the topographic constrains. Iron plough, tractor, thresher, pump set (water), sprayer, etc are the common types of equipments used in Nepal.

E. Capital investments

There needs agricultural running capital especially in the seasonal basis but small farmers are in search of such capital. It is common to obtain loan for the agriculture from different sources. Agricultural credit was taken from the institutional sources like banks but considerable numbers of farmers also take it from non-institutional sources. Long and tedious bureaucratic paper works and processes discourage farmers to go through legal and institutional channel.

F. Cropping patterns

The cropping systems in Kathmandu valley are reported in table 6.1.11 (a). Three distinct cropping systems are prevalent in the valley: rice-based, maize-based, and vegetable-based. Rice-based cropping systems are predominant, although vegetable-based cropping systems are more common than in other regions. Vegetable-based cropping systems are being adopted by farmers in other hill areas of Nepal.

Adoption of Vegetable Material

Seeds are the basic input for vegetable farming and outside sources for quality seeds are not always reliable. Most of the vegetable material (or varieties of different vegetables) have been adapted, acclimatized, and naturalized by local farmers, and these varieties have acquired indigenous traits due to the processes of natural selection and genetic shift. This indigenous germplasm has also been used as a source of breeding material by leading vegetable agronomist of Nepal. Although most local farmers lack formal training in plant breeding, they use individual/mass selection procedures for crop maintenance and seed production. For example, medium- and early-maturing plants are allowed to flower and set seeds. Seeds from these plants are then combined and used as planting material in the next season. This practice was found very successful and vigor was maintained. Improved and quality seeds are mostly in scarcity.

Cropping pattern prevailing in Kathmandu valley is presented below.

Table: 6.1.11 (a) Existing paddy and maize based cropping pattern of Kathmandu valley

a. Irrigated area		
1. Paddy-Wheat-fallow	2 Paddy-potato-potato	3. paddy-Mustard-fallow
4. Paddy-potato-fallow	5. Paddy-fallow-potato	6.Paddy-vegetable-vegetable
7.Paddy-Potato-radish	8. Paddy-fallow-daddy	
Partially irrigated area (not perennial source of water)		
1. Rice-wheat-Fallow	2. rice-Mustard-Fallow	3. Paddy-Wheat-Mustard
4. Paddy-potato-fallow	5. Paddy-Oat-fallow	6. Paddy-fallow-potato
7. paddy-Pea-potato	8. Paddy-fallow-Fallow	
Non-irrigated area (dry-slope land area)		
1. Maize-Kodo-fallow	2. maize-Soyabean-fallow	3. Maize-Mustard-fallow
4. Maize-buck wheat-fallow	5. Maize-Potato-fallow	6. Maize-Vegetable-fallow
7. Maize-mas-fallow	8. Maize-fallow-fallow	

Source : District Agriculture Development Centre, 2007, Kathmandu

One of the reasons for shortage of suitable seed is lack of sufficient information on seed production aspects despite their keen interests and desperate needs. Another reason is the introduction and extension of vegetable crops with very difficult seed production methods. Vegetable types adopted and maintained by *Jyapoo* farmers in Kathmandu Valley is presented in the appendix table.

In some of the area in Kathmandu valley farmers who are fully involved in the commercial horticulture, use vegetable based cropping pattern (table 6.1.11,b).

Table: 6.1.11 (b) Existing vegetable based Cropping Pattern of Kathmandu Valley

First crop	Months	Second crop	Month	Third crop	Month
Vegetable-based cropping patterns					
Beans/cowpeas	May-Aug/sept	Rasish/Turnip	Aug-Dec	Onion/Garlic	Dec-Apr
Carrot	May-Aug/sept	Beans/cowpeas	Aug-Dec	Radish/Knolkhol/turnip	Dec-Apr
Chilli	May-Aug/sept	Broad lead Mustard	Aug-Dec	Potato/Radish	
Chilli/ginger	May-	Winter Vegetables	Aug-	Winter vegetables	

	Aug/sept		Dec		
Colocasia	May-Aug/sept	Broad bean	Aug-Dec	Mustard	
Gourd	May-Aug/sept	Spinach/cress/coriander/fenugreek	Aug-Dec	Peas/turnip/carot/sinach/Cress/coriander	
Okra/Pumpkin/cucumber	May-Aug/sept	Cole crops	Aug-Dec	Squash/cucumber/potato	
Soyabean	May-Aug/sept	Onion green	Aug-Dec	Coriander/lettuce	
Sweet Pepper	May-Aug/sept	Potato	Aug-Dec	Late cauliflower/cabbage	
Tomato/egg plant	May-Aug/sept	Radish/mustard	Aug-Dec	Onion/Potato	

Soil preparation

Human labor is used for soil preparation in the valley as the use of animal labor in the valley floor is prohibited for religious reasons. Land is prepared by pulverizing soils to allow easier root penetration, to facilitate mixing manure and fertilizer, and to help destroy harmful insects and pests.

Planting and nursery management

The choice of plantation technique is influenced by factors such as the type of vegetable, the schedule for marketing, the desired yield, and the shape, size or weight of the product. For example, carrot, radish, turnip, spinach, cress, coriander, celery, beans, and okra are sown directly. Eggplant, cauliflower, broad leaf mustard, chili, cucumber, and tomato are transplanted. Cauliflower, eggplant, and chili are also replanted for delayed production. Vegetable crops such as cress, spinach, fennel, fenugreek, garlic, onion, and coriander are sown on sunken beds, and crops such as cauliflower, cabbage, broad leaf mustard, potato, radish, tomato, chili, and eggplant are planted on raised beds. Nursery seedbeds are generally preferred near the residence or in a safe corner of the main field. The nursery soil is given a fine tilt and weeds, plant debris, pebbles, chaff, etc., are removed. After preparation of a raised or sunken beds, 2-5 kg/m² of well decomposed compost is mixed with the nursery soil. Seeds are usually broadcast and covered with a mixture of soil, ash, and compost.

Irrigation

The timing and quantity of irrigation water to be applied are influenced by conditions such as the type of crop produced, type of soil, temperature, stage of plant growth, etc. In Kathmandu valley, soils are heavy clay, so drainage is more important than irrigation for successful vegetable production, especially during the monsoon and autumn seasons.

Figure: 6.1.11 Irrigation channel in rice field in Lalitpur

Good drainage is essential in rice based vegetable cropping patterns and for rainy season vegetable production. Crops such as cauliflower and cabbage, which are highly susceptible to high soil moisture, are planted on raised beds.

Weeding and other cultural practices

Weeding is mostly done manually, and there was no report of herbicide use. Weeds are fed to animals or are composted, depending upon the distance of the farm from the household, the type of animal raised, and the quantity and type of weeds gathered. Vegetable growers of the Kathmandu valley have traditionally practiced biological methods to control insects and diseases in vegetables. For example, when garlic, onion, carrot, ginger, basil, dundu, chive, and coriander are inter planted with Brassicas and other vegetable crops, the incidence of feeding and sucking insects on vegetable crops is low. Mixed or companion crop planting also promotes the population of predators of most harmful insects.

Table: 6.1.12 Crop calendar of Kathmandu valley

	Months											
crops	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Maize												
Soyabean												
Taro												
Yam												
Chilli												
Okra												
Runner bean												
Ginger												
Turmeric												
Potato												
Radish												
Leaf Garlic												
Spinat												
Onion												
Paddy												
Onion												
Couliflower												
Potato												
Raddish												
Tomato												

Traditional intercultural practices are reported to control insects. For example tobacco leaf extracts and washing soap solution for aphids and smaller sucking insects. Similarly garlic, clove extract, and kerosene oil to prevent caterpillars, cutworms, and aphids. Leaf and leaf extracts of chinaberry *(Melia azedarach* L.) as an insect repellent. However, such practices are being rapidly replaced by indiscriminate use of pesticides, causing concerns for public health and the environment.

Harvesting

Harvesting vegetables is labor intensive work than harvesting other food or cash crops. Most vegetables are harvested in more than one batch. Rainy periods and early morning hours are avoided for harvesting. About 5 percent losses are accounted for the post harvest loss in case of vegetable crops. Usually bamboo baskets usually called *kharpan* or *Doko* are used for transporting harvested vegetables.

Vegetable production

As vegetable production is one of the early businesses of the valley dwellers, where cultivation of cauliflowers, tomato and cucurbits are done with high priority in every season. Among the districts of the valley, Bhaktapur grows maximum amounts of vegetables compared to other two but the productivity is very high in Kathmandu. The trend of vegetable cultivation and productivity is increasing in later years due to availability of improved agricultural inputs but total production is not in increasing trend (table 6.1.13). This trend is attributed to the transformation of horticultural land into other land use purpose more precisely for the building purpose.

Table: 6.1.13 Production and productivity of vegetables in Districts of Kathmandu

	Cultivation Districts		Vegetable Commodity			
	Production	Unit	Cauliflower	Tomato	Radish	Cucurbit
1	Bhaktapur	ha	950	8	100	100
2	Lalitpur	ha	47	26	52.5	
3	Kathmandu	ha	298	55	50	175
	Productivity	Unit				
1	Bhaktapur	M Ton/ha	12.71	30	20	20
2	Lalitpur	M Ton/ha	9.59	11.11	20.2	0
3	Kathmandu	M Ton/ha	14.3	20	20	18

Source : Vegetable development Division, NARC, Khumaltar, 2006

Problems related to vegetable farmers

Our survey data showed about 30-50% wastage due to lack of storage or post harvest processing facilities. The medium sized farmers are the major victims. Urban vegetable farmers have faced a number of problems which are summarized below.

1. There is scarcity of improved seeds, even if seeds available they are not trustworthy.
2. Disease and pest problems are serious. Therefore they use pesticides for all types of insects and pests putting a strain on their economy.
3. Farmers rush to the nearest agro-vet shop to seek for advice at the first sight of insect or disease. They usually sold large number of chemicals and recommended very high

rates of application because the shop keeper's intent is maximum sale and profit. This causes a serious health hazard to the consumer.

4. The market is very unstable. The middlemen ensure maximum benefit for themselves by controlling the price of the vegetables.
5. The urban poor need to be trained on how to preserve unsold vegetables for use in the house and to market preserved vegetables for cash.
6. The government has identified and selected pocket areas for vegetable cultivation but the growers received very little support. The technicians are few and over worked. They don't have traveling time.
7. In some areas, farmers have suffered due to misunderstandings and confusion about authority and responsibility between two or more policy making institutions.
8. Vegetable farmers do all cultivation activities manually-mechanisation is nonexistent in most of the peri-urban area of Kathmandu valley due to topographic factor.
9. Bio-pesticides are not popular because their impact is slow, they are difficult to make and need large quantity for application.

Improving vegetable farming

Overhead production loss is primary problem to the resource poor farmers. Present research work concluded that the following points are suggested to increase and expand vegetable farming by subsistence farmers in a sustainable manner.

- Promote those vegetable crops, the seed production of which is possible, simple and easy to operate for common farmers. Self-pollinated crops should be preferred when starting. This should then be gradually followed by often-cross pollinated and highly-cross pollinated crops. Priority should be given to indigenous vegetable crops.
- Impart training on production, post-production and post-harvest activities related to seed. If possible, establish small seed or plant producer groups. Develop a system so that produced seeds are distributed or exchanged or bartered on cash or kind within the given command area. This may be extended to inter-command areas as well if surplus seed is available.

6.1.4 Stakeholder analysis for land evaluation

Stakeholders are those whose interests are affected by the issue or those whose activities strongly affect the issue. Stakeholder Analysis is a vital tool for identifying those people, groups and organizations that have significant and legitimate interests in specific land issues. Clear understanding of the potential roles and contributions of different stakeholders is a fundamental prerequisite for successful participatory agricultural governance process, and stakeholder analysis is a basic tool for achieving the understanding (Hemmati 2002). As such, four group stakeholders are involved in the analysis.

a) Local Farmers

Farmers are the group of people whose livelihood is closely ties with land. The farmers felt that cultivation of the crop accordance with the capacity of the soil and land type could be beneficial for cultivation of crop for both commercial as well as domestic consumption. Existing traditional pattern of cultivation do not care for the climate and soil. They were mostly concerned about the increase in production. It is therefore suitability identifies land area which brings more production with existing amount of input. So, local residents would be in favour. The local residents acknowledged the suitability result to cope up with the fast growing market channel. At the same time, it led to mitigate the problem of soil quality degradation. However, farmers felt that the local government officials is the main responsible body to set out decent market channel for the vegetable they produce after identification of suitable cropping area. The government authority should keep hold in the market to adsorb the product. In addition, some families stated the appropriate mechanization input can be implementation after land suitability assessment so as to make it more sustainable cultivation. Rational application of the suitability outcome guarantees sustainability of vegetable cultivation.

b) Environmentalists

The environmentalists mostly were concerned about the pollution being generated in the city and amplification could be seen by happazard and rampant expansion of buildup area in potential agriculture land. The most important benefit is the control of the soil erosion. Identification of the slope and erosion potential is prime job of suitability analysis. This definitely helps developing suitable crop zone for particular vegetable. Development and degrading the urban environment and the existing green spaces were not enough with the fast increase of urban population.

Hence, a new suitable vegetable cultivation area even in the urban and peri-urban area could help mitigating urban garbage in compost form. So it could effectively be able to deal with the pollution problem to some extent. On the other hand, the land suitability assessment should approach the water source, and be located with appropriate slope and good surface water quality. It helps in water problem in the growing area like Kathmandu. At the same time other environmentalists pointed out the suitable area for particular vegetable, cereal, fruits and so on can build up like a new park, that contribute in many respect to decrease air pollution and carbon sequestration. Thus it can be showed that further concerned on both economic benefits and ecological benefits should be considered in future plans.

c) Urban planners

Six experts were invited to the group discussion. This group provided the most vivid discussion, mostly about the potential for the development of tourism and the problems existing land utilization for various purpose. Four urban planners acknowledged that suitable agricultural area identification could not only play a role in the agricultural development of an area, but also help on setting planning for the allocation of the build up area and designate area for the urban expansion. This further could help to develop tourism in area like Kathmandu to attract more tourists just because of its rational layout and high landscape quality. The ecological benefit of rational use of land for specific crop is also immense. They felt the most important was that green spaces can effectively clean air, improve process of soil stabilization and help on climate stabilization. Of course there are social benefits such as improving landscape quality, historic culture value and economic benefits were not very important. Overall, the group accepted the comment that the problems existing in the present cropping system were because it did not understand capacity of the land for systematically planned agriculture. So the urban planners had responsibility to solve these problems by planning an urban area suitable in many aspects through understanding capacity to the cropping as well.

d) Local government officials

The officials concern more with setting up plan for the future development. It is their duty to designate the area for specific type of utilization, for which they need first to consider the existing land use. A separate site for built up areas should be allocated so that rampant scattering of industries and other construction does not engulf cultivation area. Such a conflict will appropriately solved by the suitability analysis. Since analysis incorporate environmental criteria, social factors and economic parameters, so that more reality would be added on the suitability job. Increasing population density and decreasing per capita land area can be balanced. Land fragmentation problem can also be managed through legal framework so that land retains its capacity to meet need of mankind. Future planning for the environmental pollution, soil erosion hazards, crop development, city expansion, road network extension and many more facilities can be handles with optimum efficiency, if result of land suitability is taken into account.

6.1.5 Discussion

Soil parameters of the investigated area reveal that soil quality seems to support vegetable cultivation. Land surface has gentle slope. Sufficient irrigation facilities are lacking. Good top soil depth with moderate organic matter content. Fertility of the soil is more about temporary parameter and can easily be enhanced by external application of fertilizers. Lower the elevation, higher the clay content in the soil. Moderate diversity of soil group in valley related with the variation in soil parameters. Due to the physiogeographical setting Kathmandu valley had been using vegetable cultivation from the very beginning. Wide range of vegetable of indigenous varieties used to cultivate in traditional manner. Intensification in peri-urban agriculture needs improvement in traditional farming system so that optimum benefit can be achieved for growers (Gautam, 2004).

Recently urban growth in fast rate with high influx of the migrant cause valley land area under pressure. High rate of fragmentation and conversion of agricultural land into non agriculture is main problem. This situation leading to decrease in R/C ration, hence less benefit goes to the farmers. So, urban sprawl is ongoing problem in many growing cities including Kathmandu (Pradhan and Perara 2005), had to be managed on time to keep pace of vegetable development in high standard. Farmers are the main target group of this analysis to be benefited directly. Success of research result is to address the need of target group (Hemmati 2002). This model of land evaluation helps farmers and vegetable growers to realise potentiality of their land parcel and required management procedures. Besides, urban planners, experts and environmentalist are also targeted to share the utmost benefit.

6.2 Land Resources Inventory and Land Mapping Units

Main aim of this chapter is the generation of Land Information System (LIS). Spatial distribution of land attributes will be represented into thematic map to be used for the suitability evaluation. Spatial information and tabulated content of non spatial information on thematic maps will be overlaid using GIS software so as to develop land suitability maps for the development of vegetable crops in Kathmandu Valley. Land information system developed in this chapter could be used as model for similar purpose in similar areas in Nepal.

6.2.1 Land Information System (LIS) databases

The interaction of human societies with land is becoming crucial for the economic, social, political and environmental development. Organised display of the land information is very important to make decision of land use. Land Information System (LIS) is one of the intuitive components of the Geographic Information System (GIS). Various aspects of LIS such as capturing, storing, processing, managing, analysing and disseminating the land information have tremendous impacts on result output. Spatial information is the crux of the LIS and non spatial information is also contains equal importance. Those together can play the leading role for building and maintaining a LIS for particular land area. Introduction of geographical information system has impacts relate to institutional, legal, financial and technical issues, and need to be carefully planned and managed to build and maintain a LIS. Hence the tasks of building, operating and maintaining LIS require clear strategies that should adopt established framework.

Land suitability evaluation by nature is a complex process which integrates information from the related sector like physical environments, social parameters, economic condition of an area and so on. When non-spatial information is integrated with LIS, a new approach needs to deal with, that is said to be multi-criteria land suitability evaluation. This includes the physical environment, social-economic conditions along with crop agronomical requirements regarding the crop specific evaluation. On the top of all, digital information in the form of soil map is the core of process.

Application of computer technology with updated land information system in Nepal is not yet been developed. Computer added cadastral system of land management was started from the Ministry of Land Reform and Management (MLRM), Department of Land Information and Archive (DoLIA). For managing and controlling the use of land and resources, a reliable LIS is necessary. The LIS is required for timely supply of reliable land information to all its users at an affordable cost. Since such tasks are complex in nature, time consuming and costly, it requires the realistic strategies to carry out its tasks. This chapter aims to prepare LIS of Kathmandu valley. This could be real time, realistic, easy to use model to be used for land evaluation. Further extension of the LIS in the countrywide, this model would play base line information source. All the stakeholders for example farmers, urban planners, municipal workers, etc. would appropriately benefit from this LIS.

Consideration of LIS preparation

The LIS database for land suitability evaluation in Kathmandu valley is based on some basic considerations. The database development must be consistent and convenient for accessing, updating figures and transferring to the related specialised software. Providing sufficient and accurate information so as to assess objectively the situation and the changing trend of land use and setting up models for prediction, analysis and assistance to sustainable land use.

The input information includes both map information i.e. spatial and attributive information which is non-spatial. The spatial information must identify the projection, co-ordinates, map scale and the annotations as well as the consistent attributives for each type of thematic map. Non spatial attributive data must be prepared in well designed tabular forms with every kind of information and special attention has to be paid to make it easy access for editing data in special software. As for arranging information in the system, each thematic map will have 1 or 2 layers of information, depending on the content and structure of the information. The spatial data can be created either in vector or in raster format. Each type of data has a different way of drawing map for a specific geographical region. The vector geographical data represent the geographic objects by a set of co-ordinates including points, lines, area and set. The raster geographic data represent geographic objects by a set of pixels; each pixel has a certain value denoted by digital number. The attributive data in LIS can be code values, or actual values. Code values are integers, while actual values can be either integers, real numbers, logic or character and string. Thematic map prepared for the LIS of Kathmandu has prepared in scale of 1:25,000. In this study, the soil data are the main data source for LIS with developing other layers of information.

Database generation

Information in the database includes attributes with map information and layer information. They all have special consideration in terms of code used and represent in the tabular form. Appendix 3 shows the detail requirements of the attributes to be included in the database.

Land use structure

Thematic map of Kathmandu valley includes a layer of information which shows existing land use types. Agricultural land, build-up land, forest and shrub area, water bodies etc are included in the map. Each land use categories has demoted in the given format with attribute data (table 6.2.1). The structure of which is presented as follow.

Table 6.2.1 Structure of land use attribute for LIS database

Objects	Field name	Type	Width	Unit
1. Land use types	Lu_type	Char	30	
2. Code of land use types	lu_Code	Char	16	
3. Area covered by each land use type	Area_ha	Num	16	ha

Land suitability unit information:

For the purpose of using to delineate lands for vegetable crops in Kathmandu valley the form system of LIS and database is necessary for the demand of sufficient, accurate and convenient information on environmental and socio-economic factors. The data derive from the process of generalising and analysing information on land assessment, including land unit map, land use requirement and adapting classification analysis.

Map of land suitability will be generated with reasonable overlay of necessary thematic layers. It has basic spatial information layer. The data consist of attribute data and spatial distribution of the layer. The structure has been set as follows in table 6.2.2.

Table 6.2.2 Structure of land suitability attribute for LIS database

Objects	Field name	Type	Width	Unit
1.Soil type suitability	Soiltype_Suit	Char	4	
2. Soil pH suitability	pH_Suit	Char	4	
3. Organic Matter suitability	C_Suit	Char	4	
4. Total nitrogen suitability	N_Suit	Char	4	
5. Available phosphorus suitability	P_Suit	Char	4	
6. Available potassium suitability	K_Suit	Char	4	
7. Soil fertility suitability	Fertility_Suit	Char	4	
8. Soil water holding capacity suitability	WHC_suit	Chat	4	
8. Slope suitability	Slope_Suit	Char	4	
9. Topsoil depth suitability	Topsoil_Suit	Char	4	
10. Soil structure suitability	Structure_Suit	Char	4	
11. Current physical land suitability	Current_Suit	Char	15	
12. Potential physical land suitability	Potential_Suit	Char	15	
13. Final suitability	Final_Suit	Char	6	
14. Area	Area_ha	Num	10	Ha

The information layer in the thematic layer map of Kathmandu valley consist of

1) The main information source is land unit data presented on land unit map to establish connection with land use requirements of vegetable crops. Majority of the criteria include of soil and land types. To the degree the agronomical requirement of the crop satisfied by land quality gives the measure of suitability level. The detailed will be described and analysed in the preceding sections.

2) Besides land unit data, land utilization requirements of fruit crops are also important data source which connects the real conditions of the study area with the development demands of certain crops.

Other non-spatial information for land suitability assessment like: climate, agricultural land use, infrastructure for agricultural production, population, labour force, and other natural and socio-economic factors are also a system of data organised in the form of LIS database with appropriate software. Upon rational analysis of the available aforementioned data, suitability ratings according to FAO system of land evaluation will be developed for the whole of the study area.

6.2.2 Generation of land mapping units and thematic maps

The GIS model may be vector-based or raster-based model. The raster model is based on a regular grid of cells that is placed over a study area. For each cell, thematic information is recorded about the underlying location, e.g. land use at the location. Each theme can be represented by a grid layer. In vector-based models, points, lines and polygons represent the geographical objects in the study area. Present study uses vector based model for each of the land mapping unit as geographical objects of the study area for every thematic maps. Difficulties on using raster based model for building up thematic map is topographic set up. Land areas of single land mapping units are not homogenous. Setting up of the spatial resolution is found to be difficult task, where information is short fall. Thematic information about these geographical objects is stored in a separate attribute table. Every row in the table represents one geographical object and every column represents an attribute describing the geographical objects. A unique identification code is attached to each object in order to link the attribute table to the geographical objects. Creating this link is only possible when every row in the attribute table starts with the attribute ID of the corresponding geographical object.

Thematic map consists of information distributed spatially in the units of the map itself. Such units in the map are names as Land Mapping Unit (LMU). They are the basic constituent of thematic map. Therefore, LMU is defined as a land plot which is specifically identified in the map with distinct characteristics. The characteristics within each LMU homogeneously distributed differences or fluctuations in the land attributes will lead to the further fragmentation of the land mapping units into smaller pieces. From the agricultural point of view, each LMU is more suitable for specific types of cultivated crops in the existing land management condition. Each LMU is the individual entity of an area which bears characteristics of its own for example soil characteristics like soil type, soil texture, slope gradient, rootable soil depth, organic matter content and also fertility status. Such and information also reflects relatedness with the flood, erosion, etc so that allocation of the land for specific purpose can simply be defined.

Ideal delineation of the land mapping unit of the Kathmandu valley is very important for the suitability assessment. This provides basic ground for the allocation of the land to be used not only for the agricultural purpose but also for the planning to expand urbanization, and so on. Long term land use and land utilisation planning can also be done with the current thematic map, provided wise and chronological updating, correction, amendment and supplementing under the change process of related spatial databases and attributes of each land unit. Use of the GIS software for the preparation of the LMU can accommodate large number of non-land related information, but social attributes and economic indicators as well. This fact further strengthening output of the suitability evaluation of any land units.

While working for the land suitability evaluation in Kathmandu valley, following considerations were taken into account to build map of appropriate land units. More precisely, land characteristics are the basic ground of evaluation procedure, so land form and soil types are certainly carries more weights.

Considerations to delineate LMU,

a. LMUs must be drawn on the map with well defined boundaries.

b. LMU is more consistent in the criterion used.

c. LMUs must be practically significant for the specific crops to be analysed.

d. LMUs must be easily defined based on characteristics understanding land's capacity.

e. Particularities of LMUs should relatively be stable and can be used for a longtime for the assessment of land suitability.

Characterization of LMU

It is widely established fact that every land mapping unit should have certain land capability either in terms of agricultural strength or non-vegetational potential. Land Mapping Units should have distinct natures that have connection with ecology and environmental conditions of specific area. Land resources, production potential and materials characteristics of ecological aspect of study area are necessary to identify. Such information of criteria must be generated from the study site, if doesn't exist, that can be inherited from the different related sources. Quality and standard of the land mapping unit is influenced by the information used to build map.

Present research gather up digital information from different sources. International Center for Integrated Mountain Development (ICIMOD), central office, Kathmandu is the source of the land use map. Land system thematic layer which satisfy the criteria of ecological parameters and land capabilities has been adopted. Soil and Terrain Digital Database of the World (SOTER) provides the basic ground of greater soil group diversity and land units, however majority of soil data has been generated from study area through field visit and soil analysis. These data resources are in untreated forms showing only general properties for the area which is then re-organised in information layers. Merging of the land unit with identical attribute characters and separation of the heterogeneous land unit was performed. Using questionnaire, holding seminars with professional groups were used as means to generate necessary data. All the information generated is finally used in thematic maps.

Soil and terrain type plays very important role delimiting land unit in the areas like Kathmandu valley. Most of the features are controlled by the topographic factor. Therefore physiographic detail of study area is controlling process of land unit building. Therefore data for building a map of land unit in Kathmandu valley recognise ecological plots and agro-ecological sub-areas. Agro ecological areas are relatively consistent in natural and ecological conditions especially for cultivation, forestry, etc. Concerned data of research and analysis includes elements of climate, terrain, types of soil, vegetation cover and current land utilization, water source, etc. Current vegetable production can be spatially represented making attribute table.

Land Unit Map of the study area can be used to established relationship among natural elements, socio-economic conditions, cultivated crops system and potentiality of vegetable farming. Currently agricultural production of the area also gives the scenario of land ability. All criteria assembled together to give satisfactory result of suitability assessment.

To identify land units manifested on the map of Kathmandu valley, first of all, it is necessary to choose and rank criteria and then build up thematic maps under set of criteria. Choosing and ranking thematic criteria for building a map of land units is a relatively complicated job because there are often many differences of data among different areas and ecological zones. The selection of thematic criteria has depended greatly on available sources of data as well as ability, accessibility, limitation of the topic. Therefore, for the land evaluation purpose, as criteria setout in the guideline of FAO (1976) for this research, following general foundations are adopted.

- The natural conditions including soil characteristics and agro-ecological factors,
- Land use requirements and ecological requirements of vegetable crops,
- Socio-economic conditions, spatial data source and attributive data,

- Land use change of the study area in chronological order based on both primary and secondary data

6.2.3 Resource potential of land unit

Land suitability evaluation, on basis of physical or ecological condition requires criterion mostly from the soil and land attributes. Following criteria has been selected for generation of the thematic map layer, final suitability will be developed upon overlay of the following ones. Soil units of the study area follow the classification adopted FAO-UNESCO classification method

- Soil classification including main soil groups, and sub soil group
- Land sloping,
- Rootable soil depth,
- Soil texture,
- Soil fertility (cumulative level of nitrogen, phosphorus, potassium, pH, OM),
- Water holding capacity
- Land aspect
- Current land use structure

Research work intended to build spatial distribution of the climatic parameters. Temperature, relative humidity, precipitation, and evepotranspiration are interpolated into thematic characteristics. However the area of the study site is not wider enough to bring clear cut variation in the distributional pattern of climate. Socio-economic information can be depicted into the spatial form with gives more realistic figure of the thematic layer. Some of the climatic parameters like relative humidity, temperature, rainfall etc are more related with the land form like altitude, aspect, slope, etc which already had well defined thematic layer. So finally it can be conclude that on the basis of climatic parameter, given land mapping unit are not supposed to separate into further small sub regions.

Soil units

Soil taxonomy follows the classification system follows FAO-UNESCO soil classification. Code for the soil type is assigned to G. Altogether there are eight different soil types are presented where the highest area is covered by Rhodustalf Scalpic with 23% of total agricultural area. Each type of soil has difference in other associated parameters. The description of soil unit type, its area and count of LMU is presented in table 6.2.3.

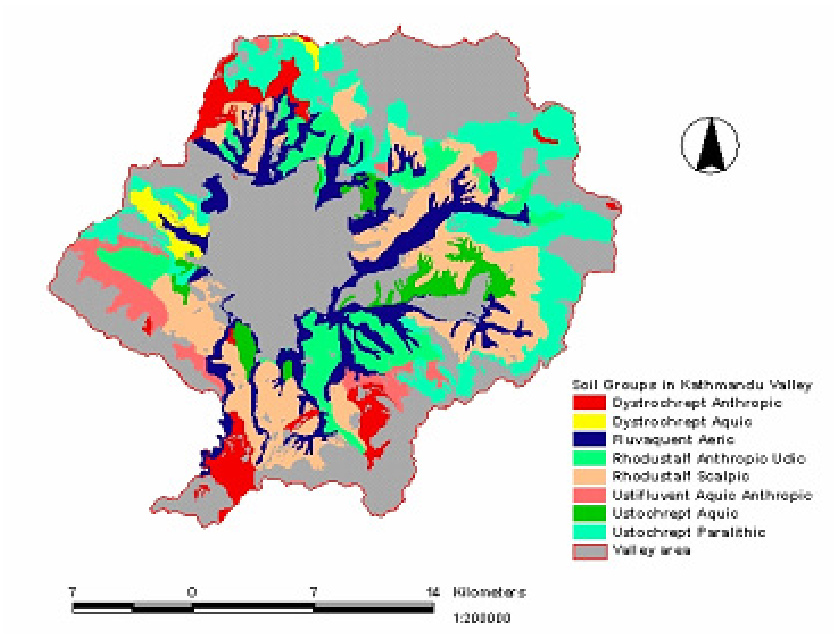


Figure: 6.2.1 Soil types in Kathmandu Valley

Table 6.2.3 Information of soil types for producing the LMU in Kathmandu Valley

Soil Texonomy	Code	Count	Area (ha)	Ag Area (%)
Dystrochrept Anthropic	G1	14	1733.24	7.4
Dystrochrept Aquic	G2	1	572.37	2.4
Fluvaquent Aeric	G3	12	4250.71	18.1
Rhodustalf Anthropic Udic	G4	22	2792.84	11.9
Rhodustalf Scalpic	G5	17	5515.78	23.5
Ustifluvent Aquic Anthropic	G6	6	1503.63	6.4
Ustochrept Aquic	G7	11	1102.75	4.7
Ustochrept Paralithic	G8	2	5965.79	25.4
Total		85	23519.33	100

Rootable soil depth

As steepness in the area increases, land possesses less soil depth. This scenario to some extent coincides with the land mass of Kathmandu valley (Baniya, 1995). Kathmandu has a different history of origin, soil depth is much higher than any other flat land of country. A drill hole at the middle of valley bottom shows that soil horizon exist up to 360m deep from the surface (table 5.7 of study area).

Table 6.2.4 Information on rootable soil depth of LMU in Kathmandu Valley

Depth (cm)	Code	Count	Area (ha)	Area (%)
> 100	D1	55	13050.22	55.49
55 100	D2	23	10163.64	43.21
30 -55	D3	7	305.47	1.30
Total		85	23519.33	100

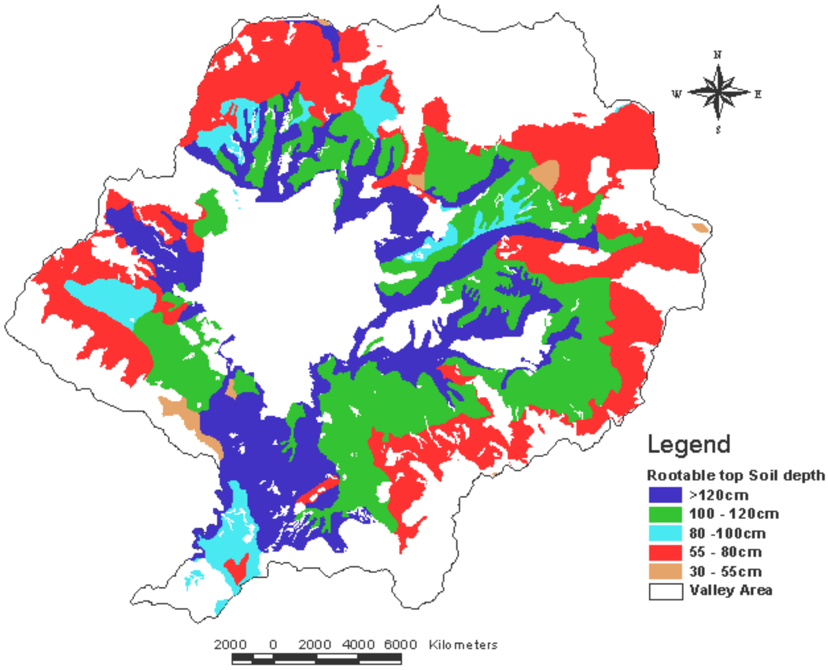


Figure 6.2.2: Rootable Soil Depth in Kathmandu valley

Present study show that 17 land mapping unit of 85 have rootable depth of the soil is more than 120cm, which come around one fourth of the total agricultural area. Similarly D2 as encoded for the depth between 55 to100cm covers 42.21% of agricultural area of valley, which accounts for 10163.64ha of potential agricultural land. Land mapping unit with lesser depth denoted with code D3 covers only about 1.2% of land area. Table 6.2.4 gives a detail glimpse of the soil depth scenario in Kathmandu valley.

Soil texture class

Texture is one of the important parameter of soil. Most of the physical characteristics of the soil depend upon texture class. The relative proportion of Sand, Silt and Clay when combined and compared to texture triangle, produces texture class of the soil.

Table: 6.2.5 Soil texture information of Kathmandu valley for LMU preparation

Soil texture	Code	Count	Area (ha)	%
Loam / Sandy Loam	T1	38	10798.071	45.9
Silty Loam	T2	17	2906	12.4
Loamy Clay	T3	25	9472.078	40.3
Sandy Bouldery	T4	5	260.97	1.1
Total		85	23519.33	100

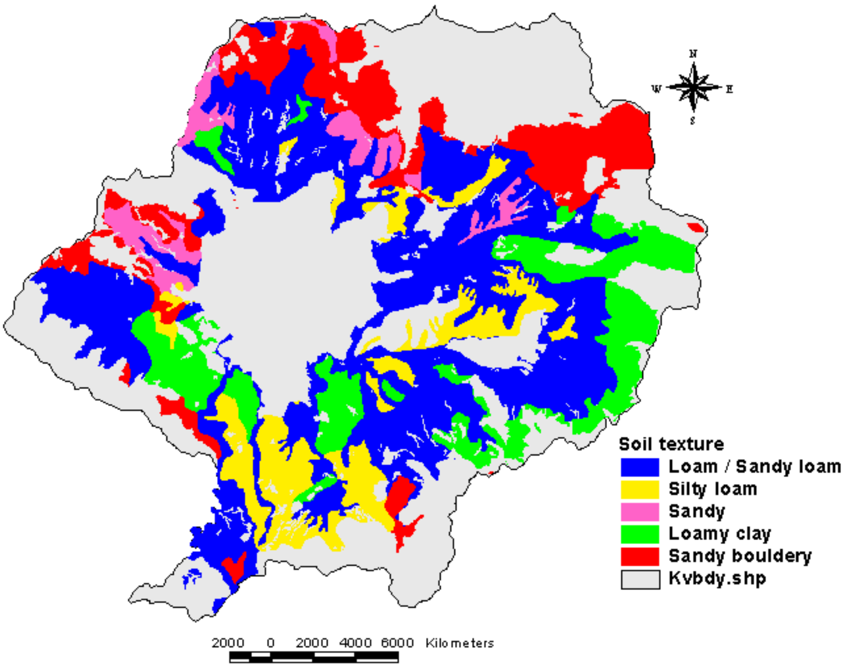


Figure: 6.2.3 Soil texture map of Kathmandu valley

As in present study, vegetable cultivation mostly prefers loamy to sandy loam soil. Such soil would be easier to work with and needs moderate irrigation facilities. Soil of the study area show 45 percent of agricultural land in valley is categorised as T1 with Loam to sandy loam texture class (figure 6.2.3). Most of the gentle slope to flat area and in the river channels posses these kinds of soil. Out of the 85 LMU, only 5 units with 260ha of land area possess rough texture with bouldery appearance. This makes working on the field practically difficult.

Land slop gradient

Kathmandu is in mid hills of Nepal; naturally it is composed of large number of slop land with different degree of slop. Here land Sloping is encoded as SL on LIS database. This plays important role on selection of the crop because it affects working pattern, irrigation style and of course cultivation mode. Increase in land slope directly proportional to higher erosion risks. There protection cost of the land is relatively high in comparison to the normal flat land. Degradation of the soil quality with slight rain fall erosion also cost for improvement. Land slope map derived from ICIMOD was found to be used by the Department of land reform, GON and drawn similar conclusion.

In present study, land level has been categorized into four slope level ranging from flat land to steep slope as given in table 6.2.6. Most of the flat land has engulfed by the urban extension. 46% agricultural land is moderately slope, where with indigenous technology, all types of agricultural practices can be carried out. Little more than one percent land is of steep slope, where agriculture activities are unsustainable; therefore it is categorised into unsuitable land for the cultivation. Most of the land area needs some extent of management input to keep safer from slope induced land degradation. The slope here is quantitatively categorized into 4 levels namely SL1, SL2, SL3 and SL4.

Table 6.2.6 information on slope level for producing the LMU in Kathmandu valley

Slope status	Code	COUNT	Area (ha)	%
Flat to gentle slop	SL1	18	4948.5	21.3
Moderately slope	SL2	51	10789.6	46.4
Undulating slope	SL3	12	7491.6	32.3
Steep slop	SL4	4	289.6	1.2
Total		85	23519.33	

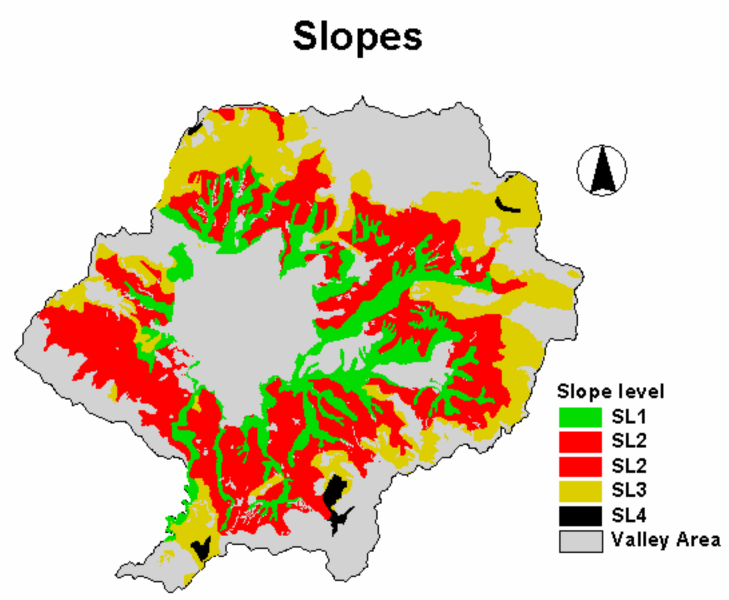


Figure: 6.2.4 Slope map of Kathmandu Valley

Soil fertility

Production potential of the soil depends upon its capacity to support plant growth. Therefore, soil fertility is the ability of soil to server as a habitat for plants and to produce yield crops or it is the natural, sustainable productivity of soil under given climatic conditions. The fertile soil has the following properties:

- It is rich in nutrients necessary for basic plant nutrition, including nitrogen, phosphorus and potassium.
- It contains sufficient minerals (trace elements) for plant nutrition, including boron, chlorine, cobalt, copper, iron, manganese, molybdenum, sulfur, and zinc.
- It contains soil organic matter that improves soil structure and soil moisture retention.
- Soil pH is in the range 6.0 to 6.8.
- Good soil structure, creating well drained soil.
- A range of microorganisms that support plant growth.
- It often contains large amounts of topsoil.

Soil fertility as indicated in the land evaluation guideline by FAO, it is denoted by alphabet p. Production potential of soil is influenced by the fertility. In fact fertility is the collective measure of the all the soil nutrients, both micro and macro more specifically, nitrogen, phosphorous and potassium. Fertility of the soil is merely the permanent attribute, but it gets constantly fluctuate within the time frame depending upon type of crop grown. Fertility also influenced by the fertility investment as well as technical handling of the land. Besides NP and K, fertility is also incorporate other quantitative parameters like pH, availability of organic matter in the soil and humus content, soil texture component and associated water holding capacity (table 6.2.7). The level of current soil fertility will help to identify the level of fertility investment and proper technical methods required for the effective cultivation of the vegetables in the study area. The soil fertility in each land unit is categorized into 3 main levels namely high (P1), medium (P2) and low (P3), spatial distribution and tabular expression are given below in table: 6.2.8 (a –f) and figure 6.2.5 (a - f).

Table: 6.2.7 Total fertility in the soils of Kathmandu

FERTILITY	Code	COUNT	Area (ha)	%
Medium	P1	35	10957.59	46.75
Low	P2	45	11805.06	50.37
very low	P3	5	674.48	2.88

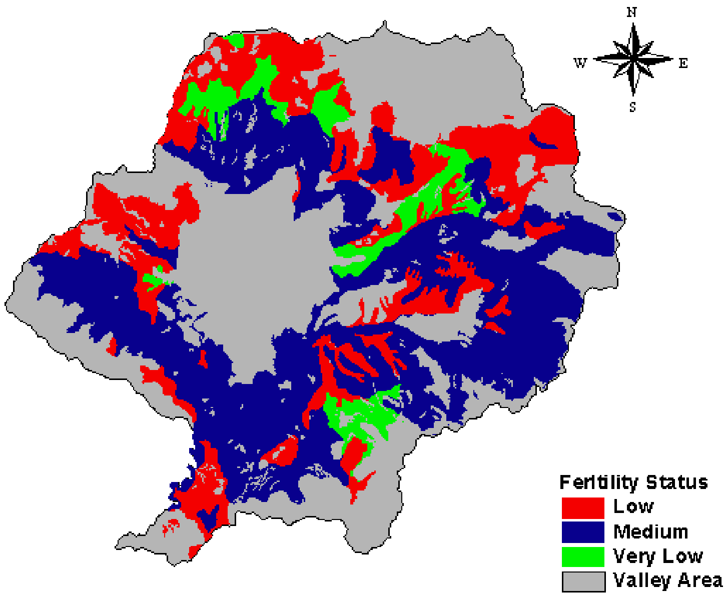


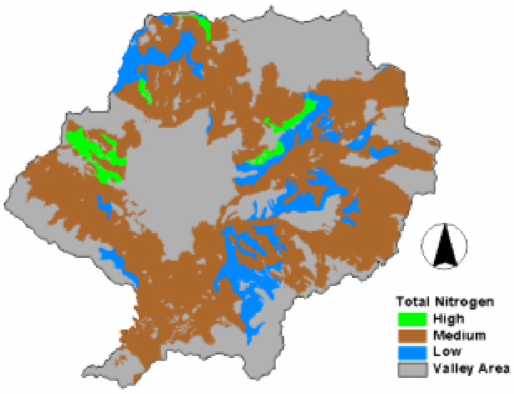
Figure: 6.2.5 Soil fertility status of Kathmandu Valley

Table 6.2.9 gives generalized figure of the fertility status of Kathmandu Valley. The fertility status of each soil group is presented in generalised form. Altogether 8 soil groups found in the area are supplied with the medium fertility status. Organic matter content of the soil groups is satisfactory and most of them rated as medium. pH of valley are acidic however the value is moderate in majority of soil types. Rhodustalf Scalpic (G5) soil type is fairly good with all fertility factor in food condition.

Figure: 6.2.6 (a-f) Map of individual attributes

Table : 6.2.8 (a-f) Fertility attribute status tables

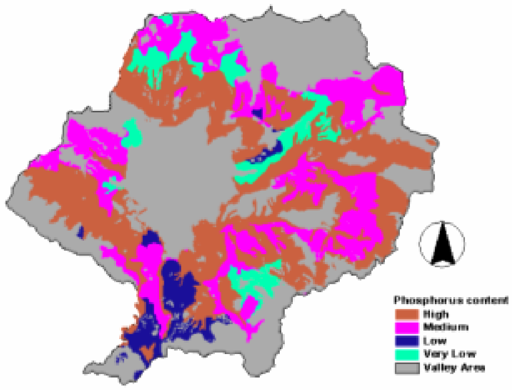
a) Map of Nitrogen status



a) Nitrogen status in Kathmandu soil

N_STATUS	COUNT	Area (ha)
High	5	830.64
Medium	63	18983.79
Low	17	3622.67

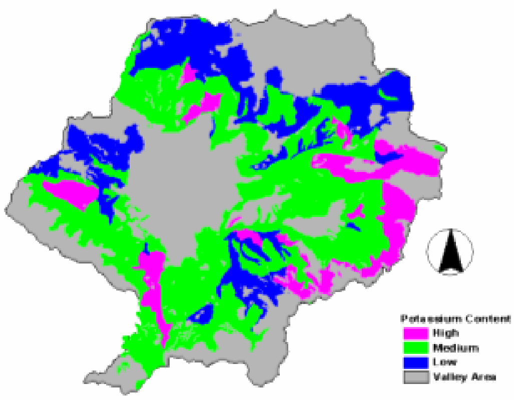
b) Map of Phosphorus status



b) Phosphorus status

P_STATUS	COUNT	Area (ha)
High	51	12052.78
Medium	20	7623.10
Low	14	3761.23

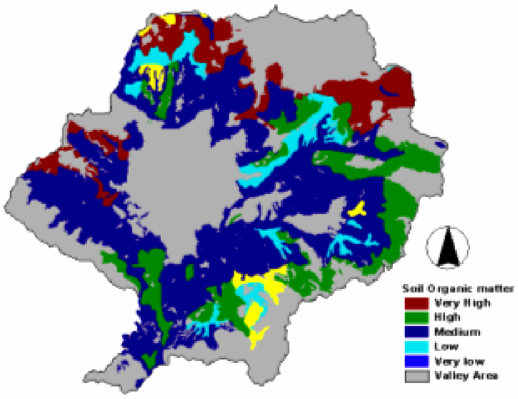
c) Map of status of potassium



c) status of potassium

K_STATUS	COUNT	Area (ha)
High	11	3969.39
Midium	53	12573.29
Low	21	6894.43

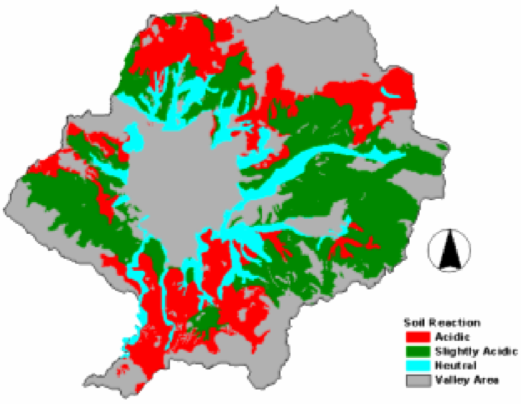
d) Map of Organic matter status in



d) Status of Organic matter

OM_STATUS	COUNT	Area (ha)
High	24	8061.15
Medium	48	13018.60
Low	8	1682.88
Very low	5	674.47

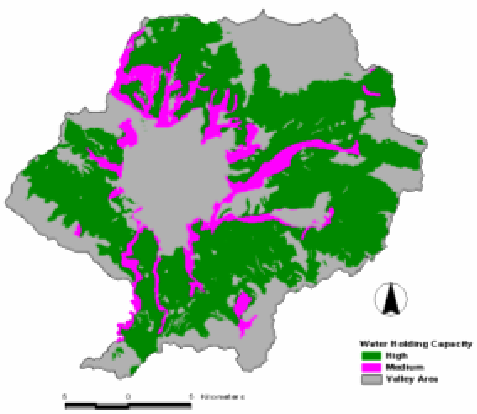
e) Map of soil reaction in Kathmandu



e) status of soil reaction in Kathmandu

PH_STATUS	COUNT	Area (ha)
High	9	3862.7420
Medium	47	11430.6370
Low	29	8143.7400

f) Map of Water holding capacity



f) Water holding capacity in Kathmandu

WHC_STATUS	COUNT	Area (ha)
High	77	19798.6670
Medium	8	3638.4520

About 5.5 thousands hectare of agricultural land with this category possess high value of water holding capacity. Other fertility factors like nitrogen, potassium and phosphorus do fluctuate even within the cultivation period, therefore mostly depends upon the external application. This is regarded as temporary fertility factor which can be corrected as and when needed.

Table: 6.2.9 Overall fertility status of the soil groups present in Kathmandu

		Fertility Factors							
Soil Group	**Code**	**pH**	**OM**	**N**	**P**	**K**	**WHC**	***p***	**Area(ha)**
Dystrochrept Anthropic	G1	M	M	L	L	L	L	L	1733.24
Dystrochrept Aquic	G2	L	M	H	M	M	H	M	572.37
Fluvaquent Aeric	G3	L	M	M	M	M	L	L	4250.71
Rhodustalf Anthropic Udic	G4	M	M	H	M	M	L	M	2792.84
Rhodustalf Scalpic	G5	M	M	M	M	H	H	M	5515.78
Ustifluvent Aquic Anthropic	G6	M	M	M	M	M	M	M	1503.63
Ustochrept Aquic	G7	L	M	M	M	H	L	L	1102.75
Ustochrept Paralithic	G8	M	H	M	H	H	L	L	5965.79

H = High, M = Medium and L = Low

Results of the fertility status of the soil types in the Kathmandu can be conclude that the over all suitability rating in the Kathmandu valley has less impact by fertility status of particular soil type. This fertility scenario not necessarily reflected in the fertility of each LMU, it is because in many LMU, they are composed of combination of soil types, aspect and slope categories.

6.2.4 Discussion

Development of the LIS for the purpose of using to delineate lands for vegetable crops in Kathmandu valley is necessary for the demand of sufficient, accurate and convenient information on land and soil characteristics. The database development must be consistent and convenient for accessing, updating figures and transferring to the related specialised software. The data derive from the process of generalising and analysing information on land assessment, including land unit map, land use requirement and classification analysis. Building of LIS was not successful as expected in the past because of lack of serous structural planning and clear strategy (Tuladhar et.al. 2004). Present LIS database of

Kathmandu has high prospectus for further extension and act as model for other area in country. Data base includes information related to resource potential of land parameters. Present study uses vector based model for each of the land mapping unit as geographical objects of the study area for every thematic maps. The information of soil and land parameters has been transformed into thematic map layer through GIS application. Total land area is divided into 85 consistent land mapping units. Spatial distribution of the climatic parameters viz. temperature, relative humidity, precipitation, and evepotranspiration are interpolated into thematic characteristics however the total area is not wider enough to bring clear cut variation in the distributional pattern of climate. The thematic maps of all physical criteria will be subjected to overlay for the suitability evaluation.

In present study thematic layers of all parameters shows that soil quality of valley is found to be fairly good. Land use should be completed that is, all land should be used; and reasonable, that is, the land should be farmed efficiently with appropriate crops and rotations and attention paid to maintaining the fertility of the land (Marsh and MacAulay 2002). A fertile soil could be described as one that provides all the plant nutrients in the right proportion with adequate aeration and soil moisture. Soil management plays a very important role in vegetable production as it maintains/improves soil fertility and provides a good medium for plant growth. Soil management is the sum total of all the tillage operations, cropping practices, lime, fertilizer, and other treatments applied to the soil for the production of a crop. Even with the land area with highly suitable condition, all the soil management operation has to be done to keep the soil in the potential status. Suitability evaluation further helps putting emphasis on particular soil management event because it identifies limitation of land area.

6.3 Result of Land Suitability Evaluation

The land suitability is the aptitude of a given type of land to support a defined use. This chapter presents the results of physical land suitability assessment done in previous chapter. Further more, incorporation of the socio-economic attributes along with physical and climatic suitability for vegetable cultivation will be done. Out put of this chapter will be suitability map depicted with the suitability degree and limitations involved. The later part of this Section offers the discussion on the multi-criteria land suitability evaluation on the basis of the entire criterion including physical social-economic and environmental.

6.3.1 Evaluation of natural land resource

Cultivation is the act of making use of land resources to get production for livelihood of mankind. Therefore, cultivation involves both land characteristics including qualities and human attitudes. Social parameter of human being determines the need moreover need make decision parameter for the type of crop to be cultivated in given plot of available land. Production from the land is based on the land capability and investment input in terms of materials and services. Land capability gives rough sketch of the land to be used for specific use for the utmost out put. Separating land area for specific use by knowing its capacity to support type of crop is land suitability classification. So the process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for a defined use.

Land suitability assessment for vegetable development in Kathmandu Valley is influenced by many fundamental parameters namely, soil and land parameters, climatic attributes, terrain and physiographic, social characteristics, cultural aspects, cultivation customs, infrastructure development, services available, market situations and many more. All of them can logically be discussed under two categories

- Physical and environmental parameters
- Socio-economic parameter

Former factor more related to the growth and development of the plant species that supply physiological need. Plant growth is influenced by components of the physical environment. Almost all agronomical need of a crop is fulfilled by components of physical environment.

Where as latter parameter is more likely to effects on final yield and handling of the product and post harvest handling is also depends upon same parameters.

Cultivation trend in society and land use practices is social and cultural traits, which makes impacts on yield of crop. From field to kitchen (from soil to consumer) or to market is affected by the socio-economic and infrastructure attributes.

For the development of the vegetable farming in the areas like Kathmandu valley needs to understand fully the land capability, which is the first and far most important aspects. Land set up and soil characteristics are of unique type. Physiographic setting allows specific crop species attains full growth in such an environment. Planning of vegetable crops begins with the selection of the suitable species based on the ecological condition of the valley. Very often local species are selected for the cultivation because of the genetic acclimatisation for specific environment. It was observed in several instances that under production and economic loss are caused by introduction of the new species. Traditional way of cultivar improvements and selection is cultural practice in many parts of valley on which farmers are accustomed. Understanding of soil quality and climatic condition assist to a greater extent on selection of suitable species of vegetable. Infrastructure development and investment of state and central government on the horticultural sector also plays role. Road access network, setting up market place and controlling price, agricultural subsidy, etc would make impact on the yield and economic benefit from the farming. In several instances, lack of proper storage arrangement caused heavy economic loss to the farmers. Distance to nearest road head and to the market is also a problem. Contrary to this, introduction of the plastic tunnel farming produces large amount of the off season vegetable, leading to good economic benefits. From these facts, it can simply be concluded that vegetable cultivation is act which need to be considered with set of conditions from all possible sector like physical environment, climatic, social, economic, infrastructure and agricultural input availability. Relationship among different influencing factors should be judged properly for selection of the land area according to agronomical need of plants, capability possess by land area, farming attitude of the society and economic potentiality with infrastructure investment in land. Similar consideration has been shown by Hossain et.al. (2007). All these criteria are considered in the order of importance i.e. ratings. Evaluation of rated component of the factors will generate land area which is suitable for the specific type of crop with degree of difficulty and limitations. The classification result will yield suitability evaluation of land area.

Suitability evaluation is carried out considering each component separately. Physical land suitability, socio-economic suitability and environmental suitability are established ones.

6.3.1.1 Physical land suitability

Based on the current land use map, agricultural area has extracted from build up area and forest region with GIS tools. As indicated in previous chapter while making land mapping units, altogether 85 homogenously distributed land units are selected. Each of the land units with their attributive characteristics are considered for the suitability evaluation. While evaluation is purely based on the land, soil and climatic parameters, it is simply called as the physical land suitability evaluation.

Condition of land could be suitable for the agricultural purpose. If suitable, it can be categorized into different suitability class according to existing limiting factors. As the LMU is the regarded as homogenously categorised for each of the parameter, degree of suitability is attributed for particular LMU. According to FAO guidelines for land suitability evaluation (1976, and 1983) classification of suitable land considers land characters with crop requirements. FAO system of classification has appropriately used in Kathmandu valley condition. Modified form of the land suitability evaluation in this case consist of three basic methods namely the subjective combination method, the limitations combining method, and parameter methods.

Land and topographic variation as seen in the Kathmandu valley allowed using limitation combination method of land suitability evaluation for the vegetable crops. Literature survey and expert consultation has forwarded to use this method of suitability evaluation, because physical land suitability evaluation for the vegetable crops always based on identification of limiting factors. Present study based on the following principal considerations

1. Principle for identification of diagnostic factors with most serious limits;
2. Principle for most important limits in consideration with dominant factors;

1. Identification of decisive factors:

It is also called as dominant factor. These are decisive and unchangeable factors in land classification, for instance: soil type, terrain, slope, soil layer depth, etc. Other factors are ordinary ones, which hardly affect the classification of land. The classification of dominant factors and ordinary factors is clearly expressed with having the presence of socio-economic conditions, infrastructure in the evaluating process. This will be minutely presented in the final land assessment results in this Chapter

2. Classifying criteria:

(1) If a dominant factor has the highest limitation level, the suitability is ranked in accordance with that level, for example: a dominant factor is at S3, the other factors are at S2 and S1, and then the suitability level is ranked S3.

(2) If an ordinary factor has the highest limitation level while the other factors (dominant and ordinary) are at lower ones, the suitability is ranked one-level higher, for example: an ordinary factor is at S3, the other factors are at S2 and S1, and then the suitability level is ranked S2.

(3) If two ordinary factors are at S3 whereas all dominant factors are at S1, S2, the suitability level is ranked S2, or from N to S3, and from S2 to S1;

(4) If more than three ordinary factors are at the same level, the suitability level remains the same.

Literature survey and field study has identified list of land and climatic factors which is catagorised as the dominant and ordinary factors. Relationship with crop and degree of influence are the sole consideration for this categorization. The list is presented in table 6.3.1.

As presented in table 6.3.1, most of the land and climatic factors are rated as the dominant factor, which can lead large scale effects on the suitability analysis. All weather characteristics i.e. temperature, precipitation, relative humidity and sunshine hour are categorised as dominant. Similarly soil type, land slop and rootable soil depth also made dominant factors. Land aspect and altitudinal range are excluded in this category ratings because climatic parameters like temperature and sunshine durations are affected. Of the pedological parameter except soil texture, all other parameters carry less importance on making suitability classification. It is because such factors can be enhanced with necessary investment during the cultivation. N, P and K collectively contribute to the soil fertility (p). Water holding capacity (w) has close association with the textural class (t). Organic matter content and pH of the soil depends upon external input on the soil. Kalogirou (2002) suggested that the enhancement of the physical evaluation by involving climate characteristics and the development of a complete economic evaluation brings valuable results.

Table 6.3.1 Category of dominant and ordinary factors for vegetable crops in Kathmandu valley

Land quality/characteristics	**Code**	**Unit**	**Characteristics**	
			Dominant	**Ordinary**
WEATHER CHARACTERISTICS				
1.Temperature	t °	° C	□	
2. Rainfall	r	mm	□	
3. Relative Humidity	rh	%	□	
4. Sunshine hour	sh	hr.	□	
LAND CHARACTERISTICS				
1. Soil type	g		□	
2. Land slope	sl	degree	□	
3. Soil effective depth	d	cm	□	
4. Altitudinal Range	al		□	
SOIL CHARACTERISTICS				
1. Soil texture	t		□	
2. Soil Fertility	p			□
- Total Nitrogen (N)		%		□
- Available Phosphorus (P)		Kg/ha		□
- Available Potassium (K)		Kg/ha		□
3. Soil reaction (pH)	pH	-		□
4. Organic Matter (OM)	om	%		□
5. Water holding Capacity (WHC)	w	%		□

All of the dominant as well as ordinary characteristics are ranked on the basis of agronomical and physiological requirement of the selected crops. Such factors ranked in following levels;

1. High level of suitability ($S1_{AHP}$),
2. Medium level of suitability ($S2_{AHP}$),
3. Low level of suitability ($S3_{AHP}$) and
4. Non-suitability (N)

A FAO guideline for land suitability evaluation (1976) has identified non suitable land into further two sub levels, temporarily non suitable (N) and permanently non suitable (N2). For the purpose of present study non suitability class is not further separated, because once it is unsuitable with the dominant factor, it is categorised as an unsuitable category.

For the purpose of determination of ecological requirements for vegetable crops in this study base on theoretical consideration, like reference materials, agronomy of vegetable crops, specialists' opinions, and more precisely base on the local cultivation knowledge. Moreover, the classification of these requirements is the average of a set of standard criteria, which decide the limitations of different levels, below are some specific examples of ranking ecological requirement of fruit crops:

- The very first limitation farmers normally take care of the limitation to make cultivation much safer. Growth and development of plant has to be secure. So, the gap between S1/S2 is a collection of lower limitations of high suitability levels. e.g., maximum land slope for vegetable should be less then 1° to 5° but from 8° of slope gradient, crop is greatly affected, so demarcation between S1/S2 could be started right from the 5°.
- Second demarcation point between S2/S3 is considered such limitation level which could reduce the productivity to desirable extent.
- Whether the condition of land gives economical benefits both on growth as well as productivity. Input investment is much higher then the output from the field, therefore, the gap between S3/N is a demarcated with the limitations that make the crops unrealistic and un-economically benefit,

Category of Physical land suitability

Most important is the existing land or soil characteristics of particular land units. When making assessment for the land suitability for the current physical land suitability evaluation condition prevailing in LMU is to be matched with the eco-physiological requirement of the plant. More it satisfies the requirement, better will the suitability. Present GIS study shows that existing land area of the Kathmandu valley in total is 58,369.9ha. Of which ever increasing urbanization occupies 33.3% of land. Existing agriculturally active land mass is

23,519.3ha. In this area cultivation of all possible crops has been done with traditional practices, primarily paddy cultivation and maize crops. Vegetable cultivation carried out in paddy base farming system in low land and maize based farming system in uplands. Therefore, in prevailing condition, temporary soil measures for example fertility, organic matter and pH cannot be stabilized as it done for the vegetable. To make it considered properly vegetable crops should be carried out in field continuously. On the basis of land form, homogeneity of land characteristics and soil characteristics, total agricultural area is divided into 85 land mapping units.

Majority of vegetables are the annual crops. They complete their vegetative and reproductive phase of the life cycle within single season and some will continue for a year. They need annual input in terms of labour, material and preparation yearly manner for expected yield. Even though some of the land and soil factors limits effective growth and development of the plant and in turn, lowers the potential production. Those factors are called as the limiting factors. Suitability rating of the land gets altered because of the presence of one or more such limiting factors. For vegetable cultivation practices, on the basis of presence of limiting factor, physical land suitability has popularly been identified as

a. Current physical land suitability,
b. Potential land suitability

In case of current land suitability, existing condition is considered. Type of land, prevalence of soil characteristics, diversity of crop used and ways of land preparations are prevailing act to effect limiting factors. All of these have marked effects on the physiological functioning of the plant. Suitability classification of the land mapping unit with existing condition of physical parameter with potential crop is current physical land suitability. In some of the research physical land suitability has been separated as soil suitability, land suitability and climatic suitability like Bydekerke et.al. (1998). There is no opportunity to make any improvement over existing condition to enhance production capacity of the land in this condition. The current land suitability assessment is very important because it helps users to recognise the current limitations of the land area for particular land utilization. It provides opportunity to take necessary steps for the further improvement and transferring higher level of suitability in potential suitability evaluation.

Characteristics from soil, land and climate which are the main component of physical suitability is rated into high, medium, low and very low value for the given group of vegetable crops. On the basis of agronomical requirements of crops all of the characteristics are rated on the suitability ground into highly suitable, medium suitable, low suitable and non suitable.

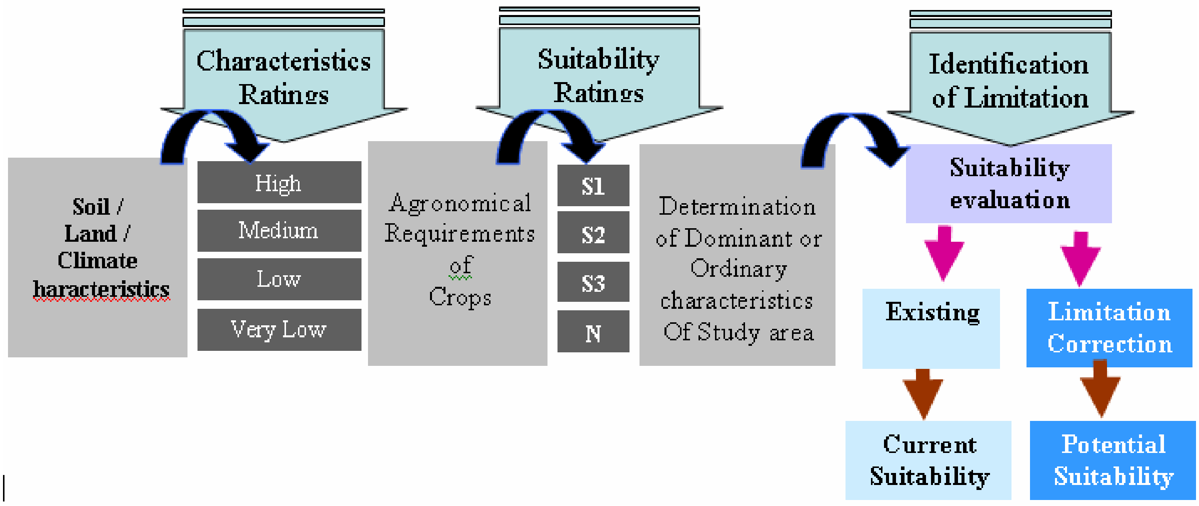


Figure: 6.3.1 Flow chart explaining model of determining suitability rating of each physical parameter.

On the other hand, limiting factors which limits the growth and development of the plant can be improved through external inputs. If organic matter is the limiting factor of any land units, it can be managed by external application of the organic fertilizers. This means that land is potentially fertile. Therefore, there is opportunity of transforming suitability rating of the land in higher suitability level. This type of land suitability evaluation is called as potentially land suitability. Potential suitability provides opportunity for the farmers to adopt appropriate action towards production enhancement so as to get expected output. On the basis of the above model of determining suitability ratings of each of the characteristic in every land unit has been done. The result has been presented below in table 6.3.2.

Temperature and climate condition for maize in Mexico was rated by Alejandro Ceballos and Lopez (2002) is similar with present study. They use it as spatial information and kept in the GIS framework. In the present study, all the land mapping units show temperature suitability as highly suitable condition. Since, average daily temperature for most of the vegetable growing period ranges from 18 to 27°C. In such case if average daily temperature above desirable limits will be rated as S2 and below required limits rated as S3. Similarly, highly suitable (S1) altitudinal condition ranges 1200m to 1600m above sea level, land mapping unit within this range given S1 and above 1600m to 2400m is categorised as S2 (MOA, 2006). Because increase in altitudinal range cause alteration in climatic factors.

Knowledge derived from the literature is subsidiary bases for the characteristics ratings. This rating corresponds to the suitability ratings (figure 6.3.1).

Table: 6.3.2 Current suitability ratings of diagnostic characteristics for vegetable cultivation in Kathmandu valley.

Land units	Area	Suitability Status of Diagnostic Characters										Suitability
		t^o	r	hu	s	p	a	t	d	w	sl	
1	13.06	S1	S1	S1	S1	N	S2	N	S3	S1	S3	N
2	3541.75	S1	S1	S1	S1	S3	S2	S3	S2	S1	S3	S3p.t.sl
Full table including all LMU is presented in appendix table 12												

Table 6.3.2 show details of the diagnostic factors with their level of suitability for the support of the vegetable cultivation. No land unit in the Kathmandu valley falls under the highly suitable ratings. There exist varieties of limitation which eventually degrade the suitability rating to lower one. Highly influencing limiting factor for the suitability evaluation is seen as fertility factors. Of 85 land units, 24 land units belong to the $S2_{AHP}$ category. Influence of texture, fertility, and slope are seen in many land units. Altogether 54 land mapping unit are under the S3 ratings of the suitability evaluation. Figure 6.3.2 gives the current land suitability evaluation map of Kathmandu valley. Study results seven land mapping units with several slope gradient and unusable soil texture makes them fall under the category of N i.e. non suitable for any vegetable cultivation. Data analysis reveal that fertility factor alone in current suitability effects 11846ha of land area which is exactly 50% of total agricultural land area is suffering from the low fertility, it has sever effect on the suitability rating. Similarly, texture class affects some 40% of potential agricultural land area in Kathmandu, it account for 9497.27ha. Problem is too clay and bouldery soil. In case of vegetable cultivation, correction of this category needs very high amount of investment. Slope gradient is another set back for about 22% land area of valley. Long, steep slope makes land prone to heavy loss of top soil. On top of it, cultivation practices are very impractical. There some of the land unit, due to the slope gradient factor, they are rated as the non-suitable for the cultivation. Soil depth in study area seems enough for the vegetable cultivation as it crosses the limits of 55cm. Only 1.4% land area got limitation of this type. Altogether 65.8% of land area under consideration are suffering from any form of limitation and cause to degrade into $S3_{AHP}$ category of suitability ratings.

All of above limitation are associated with the soil characteristics and slope. No climatic factors are causing hurdle for the suitability evaluation. Most of the land areas in the valley lie in between 1200 to 1600m above sea level. This altitudinal range falls under warm to cool temperate climate region. Daily sunshine hour, temperature, average annual precipitation and spatial distribution of evapotranspiration are supplemented by irrigation processes are also found to be favourable to vegetable crops.

In conclusion, soil of the study area is suffering from lack of fertility investment. Application of chemical fertilizers is the temporary solution to upgrade fertility ratings, however timely application of compost manure can improve humus content and also enhance soil fertility. pH of the soil in all area are acidic in nature, but are moderate. Study also suggest for the agricultural lime application during the land preparation for the vegetable cultivation. Water holding capacity of soil is more associated with organic matter content and texture of the soil.

Table: 6.3.3 Current physical suitability evaluation for vegetable cultivation

Current Suitability	Count	Area (ha)	Area (%)
S1	0	0	0
S2	24	7273.14	30.92
S3d.sl	1	23.05	0.10
S3p	25	4633.13	19.70
S3p.sl	4	1335.53	5.68
S3p.t	10	1792.45	7.62
S3p.t.d	2	162.53	0.69
S3p.t.d.sl	1	29.35	0.12
S3p.t.sl	3	3893.20	16.55
S3t	6	3542.27	15.06
S3t.d	1	75.65	0.32
S3t.d.sl	1	1.82	0.01
N	7	760.38	3.23
Total	85	23519.50	100.00

Since suitability analysis is multi dimensional approach, it is affected by many other factors which may not be related to the land itself. Non spatial information like cultivation attitude of the society and economic ability of the farmers are also associated with suitability. Therefore complete suitability evaluation is multidimensional approach which should incorporate both socio-economic criteria and infrastructural set up.

Table 6.3.3 about current suitability shows that the limitations are caused by the nutrient content of the soil. The area of limitation is represented in figure 6.3.3 and 6.3.4. Such problems can easily be maintained by the timely application of the manure and fertilizers. Increase in the nutrient content can improve over all soil condition like soil atmosphere, soil moisture and microbial activity of the soil and so on. Situations like this can offer higher productivity and in turn shifting suitability level S3 to S2 or S2 to S1. If limiting factors are of dominant or decisive ones like slope and texture or soil depth, the possibility of making improvement is unlikely. Change in such criteria needs longer time. In such a case level of suitability remain unchanged. In case of the texture, remote chances of making improvement are always there.

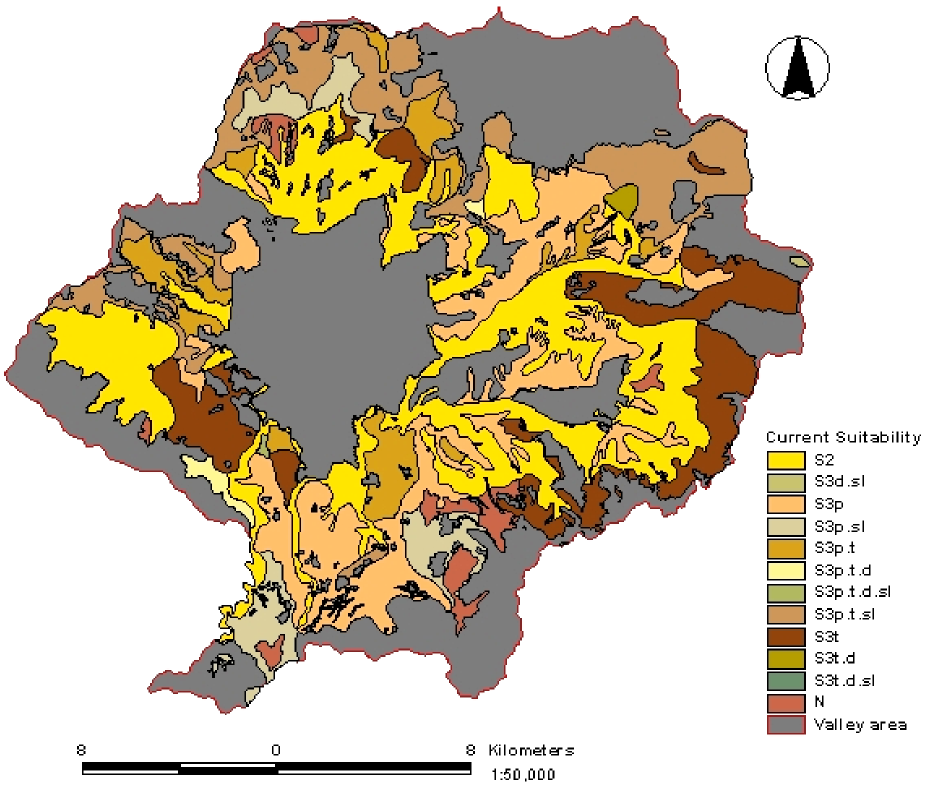


Figure: 6.3.2 Current suitability map for Vegetable crops in Kathmandu

Thus, classifying and evaluating potential physical land suitability are valuable proposals for effective land use planning. This requires close consideration into current limitations. As stated above, review and close consideration over the limitation is very necessary because that affect the growth, development and productivity of vegetable crops. Correction and upgrading over current suitability into potential suitability is much beneficial. For this, feasible measures and recommendations are proposed to improve the land, either by technical measures or by economic measures.

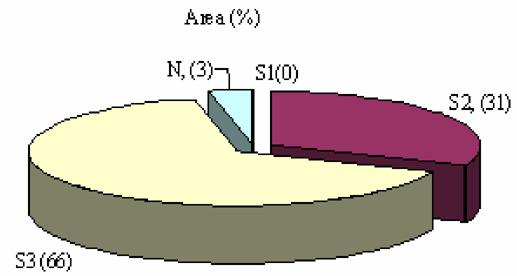


Figure: 6.3.3 Pie chart areas of current suitability

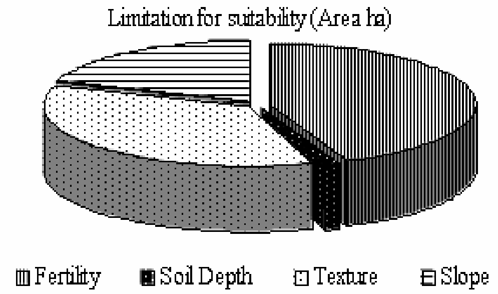


Figure: 6.3.4 Areas with the current limitations for suitability analysis.

In consideration of the current land conditions, as analysed above, there are many different limitations affecting the growth, development and productivity potential of vegetable crops in Kathmandu. To upgrade the current land suitability, it is essential to improve and overcome these limitations. The suitability after improving limitation is potential suitability. In case of Kathmandu 17% of the agricultural land area falls under highly suitable class i.e. $S1_{AHP}$ category, after necessary improvement in general or minor limitation factors. Most of them are fertility factor. 1087ha of land transformed from S2 level to S1 level. For example in the table 6.3.2, land unit 27, current suitability level of S2 with limitation of fertility factor has transformed into S1 in current suitability rating. Similarly, land unit 57 and many other transformed to S2 category form S3p, limiting factor is fertility. This condition suggests that land of the Kathmandu is potentially suitable for the vegetable cultivation. Similarly 38 percent of land which account for 9085ha falls under level of S2. In this category, many land units with S3 level has been improved and upgraded to this class. Only 313ha of land are cannot be improved to the workable category, which permanently falls under the category of N

Table 6.3.4 and figure 6.3.5 presents the potential suitability scenario of Kathmandu both in tabular data and map of spatial distribution. Potential suitability is still suffering from the severe limitation, which is very hard to upgrade and bring back into upper suitability level. Fertility factor is still limiting some 4% of total land. Soil depth is creating problem for 282ha of agricultural land i.e. 1.2% of all agricultural land. On many instances other factors like irrigation also improves soil condition of LMU. But slope for such condition is also problems. Slope of the land still effecting suitability level of 31% of land area. This is hard to be improved. Making terraces needs longer time and high capital investment, which may not be economically feasible. In the study area Slopping Agricultural Land Technology (SALT) was introduced to convert slop land into terraced land. Plantation of hedge crops in contour line and cultivation of alternate rows of permanent and vegetable crops could be effective on improving land area. This technology improves the soil condition in the slop land by slowing down speed of rain water flow and improves infiltration. Simultaneously improves ground water recharge. After keen consideration of agro-ecological requirements of selected vegetable in Kathmandu land units area transformed into higher level of potential physical land suitability classification. Details are presented as figure 6.3.6 and 6.3.7 as follows.

Table: 6.3.4 Potential suitability rating

Potential Suitability	Count	Area (ha)	Area (%)
S1	11	4087.95	17.38
S2	42	9085.10	38.62
S3d	1	13.07	0.06
S3p.d	1	21.33	0.09
S3p.sl	2	554.30	2.36
S3p.t	4	373.16	1.59
S3p.t.d	1	141.20	0.60
S3sl	1	552.28	2.35
S3t	9	1953.70	8.31
S3t.d	1	75.65	0.32
S3t.d.sl	2	31.18	0.13
S3t.sl	5	6320.93	26.87
N	5	312.67	1.33
Total		23519.50	100.00

If land users can conduct specific measures to improve and overcome the current limitations of land units, they can raise the current suitability up to 1 level, for example from N to S3, from S3 to S2, from S2 to S1 and also, can maintain the stable level of S1. In the present study, land parameter evaluation and current and potential physical land suitability rating for selected vegetable will be presented in preceding chapters.

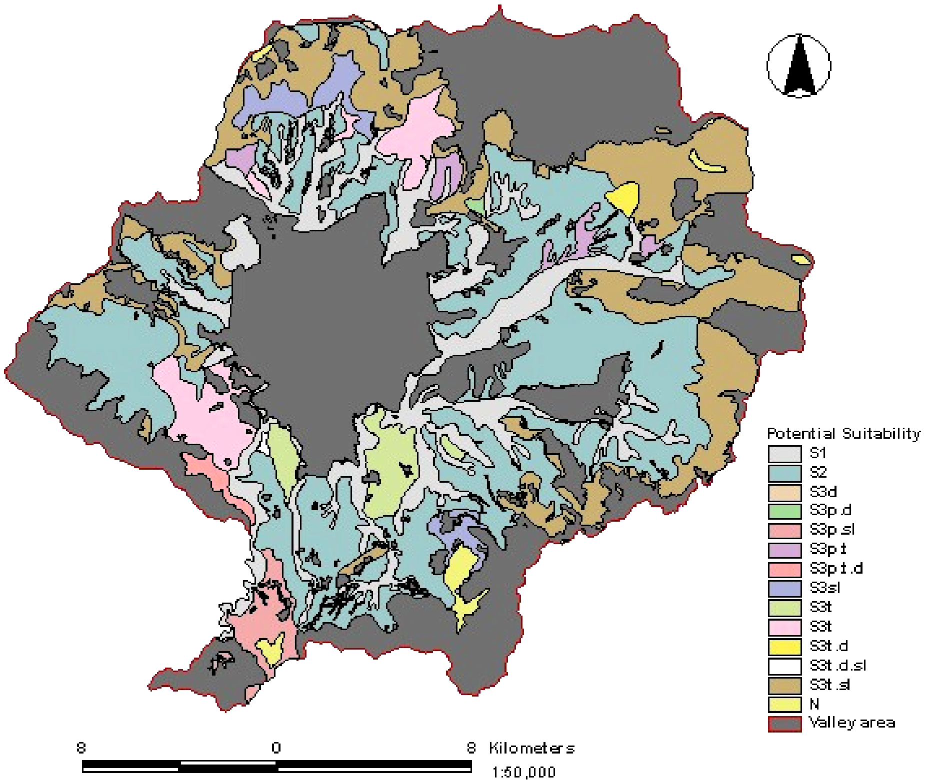


Figure: 6.3.5 Potential land suitability map of Kathmandu Valley

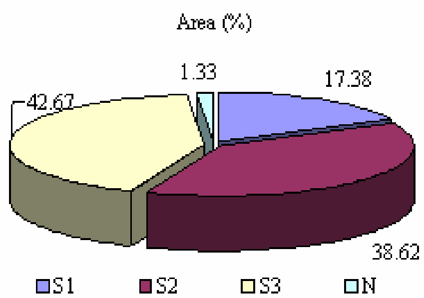


figure: 6.3.6 Pie chart of Area of suitability rating

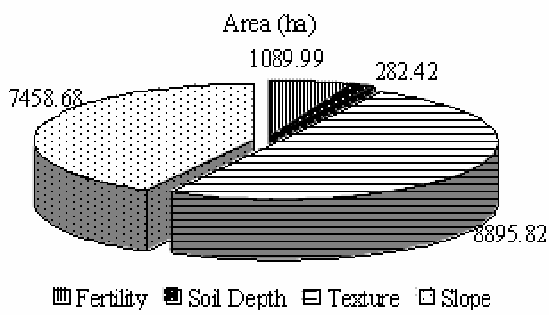


Figure: 6.3.7 Areas with limitation for potential suitability ratings.

In addition to technical measures, attention must be paid to environmental components and socio-economic matters for better result in broader perspectives. Connection of these components and attributes with their effects on suitability analysis will be discussed and present in the latter sub-chapters.

6.3.1.2 Natural and Socio-economic suitability

The influence of physical land, environmental condition and socio-economic traits on classification of the suitability levels of the land mapping unit is correlating in this chapter. Infrastructure and input availability has marked effects on the yield and economic benefits from the crop. Socio economic criteria selection is popular on GIS workings (Vo, Le & Yamada, 2003). Marketing channel and proper market information to the growers has lead to make decision over selection of type, time and varieties of crop to be cultivated. Identification of physical capability of the land area has therefore, been discussed parallel with physical parameters. The parameters in this study are regarded as the crux of the land suitability evaluation in multi-criteria analysis.

It seems strange to incorporate social traits in the land suitability analysis because land is purely physical entity, where social parameters merely exist. However some of the study has successfully carried out research with suitability evaluation in this direction (Chuong, 2007). Especially developing countries like Nepal, incorporation of the social and economic trait for the classification of land for vegetable cultivation is new which may lead to lay milestone on for new studies in the future. The model of present research can be generalised for the application in the similar area of the country as well as outside.

Multi-criteria land suitability analysis, by its title is the cumulative use of all the sectors including physical land characteristics, economic parameters and social traits. Physical parameters are prerequisite, so multi-criteria evaluation will be proceeding only if land area is physically suitable. Land area with suitability level S1 S2 and S3 are considered for incorporation of social and economic component for further analysis. Non suitable land area (N1 and N2) are omitted from suitability evaluation. Figure 5.4 in chapter 4 of methodology illustrated detailed outline of the suitability ratings.

6.3.2 Selection of criteria for land suitability evaluation

Suitability evaluation always based on evaluating criteria, which is determined with the help of varieties of information sources, field survey, group discussion and available secondary data sources. Sustainable land management guideline (FAO, 1993) forms the framework for setting up evaluating criteria and alternatives.

Criteria selection for the suitability assessment in the Kathmandu valley has certain background. They are raised mainly through PRA with vegetable growers and selected cautiously with recommendation from the experts and policy makers. After careful consideration and criteria selection for the existing realistic local conditions, present study has decided to set up criteria in three different hierarchical levels. First level consists of the main group of criteria incorporating environmental, economic, infrastructural, and social criteria. FAO (1976), Hossain et.al. (2007), Choung (2007) have used 3 aforementioned main criteria. Physical and infrastructural criteria also very important to be considered. In context of Kathmandu valley, three main groups of criteria are selected with careful consideration of literatures and bio-physical condition. Every criterion has number of criteria available. It is very important to scale up the criteria and apply them for multi-criteria suitability analysis. Qualitative assessment was applied to select required number of sub-criteria. From the list of sub-criteria, vegetable growers and extension workers are allowed to select number important and influencing parameters for vegetable cultivation in Kathmandu valley. The selected parameters are subjected to discussion with the experts. Literature aided selection procedure concluded with selection of in total 15 sub criteria from 3 main criteria. These sub-criteria make second line of evaluating criteria. Here economic-infrastructural group has six sub-criteria, the social group has five sub-criteria and the environmental group has four sub-criteria (table 6.3.5). In present research second level of criteria has not been fragmented further into smaller criteria; however alternatives of the sub-criteria are subject to make quantitative analysis for the suitability rating of individual land units. Therefore, this research consists of 3 main criteria with 15 sub-criteria. In the same way a double track approach was followed to compare land suitability as perceived by local farmers and through evaluation of expert judgment was also done by Cools et.al. (2003) in Syria**.**

Fundamental of setting up criteria and sub-criteria can be summarised as follows.

1) Existing cultivation pattern adopted by farmers are greatly affected by the current physical land parameters. Economic status of vegetable growers and infrastructure development of an area also plays role on production. Social attributes leads decision on type and varieties of crops to be planted and adoption of cultivation pattern. Therefore, this situation is reviewed by experts and set up as three main criteria. Broken down into sub criteria with degree of difficulties that creates for the cultivation, here each alternative carries score value corresponding to the existing challenges offered within piece of land.

2) Economic limitation is one of the prime causes to limit vegetable cultivation and production process. Production related with the income from the farm, influencing R/C ratio. This has further been closely linked with the availability of agricultural inputs like fertilizers as well as technical service. Therefore, setting up sub-criteria was tough job, which needs successful consultation with the farmers. It is also important on finding influencing factors and trace out degree of difficulties arises with socio-economic status of farmers on each land units.

3) Very important response of the farmers on choosing vegetable crop is spontaneous which primarily based on the market prices. Other market parameters like product quality, value addition, demand and time are not seriously considered. This situation has over shadowed the role of physical land condition on crop growth because majority of respondent had limited knowledge. On top of this, more attention has been drawn by low economic condition of land users.

Therefore, many of the land users fail to choose appropriate crops in relation to market demand and land prospectus. So it is advised to combine all of the above methods for long-term as well as seasonal selection of the vegetable varieties for the specific land units. From above discussion, following criteria with sub-criteria are considered for study. Furthermore, for purpose of GIS analysis each criteria and sub criteria have to be provided with appropriate codes to be used as field name in GIS database as shown in table 6.3.5.

Each sub criteria is provided with several alternatives that differ in different land units, community level and household condition. Site specific importance of every alternative is assigned with appropriate score value. The score value represents possible influence on crop cultivation in that area. Score of each of the alternatives that are presented in the table 5.8 of methodology i.e. in chapter 5.

Table 6.3.5 List of evaluating criteria and sub-criteria considered for Kathmandu valley

	Evaluating Criteria	**Code**
Criteria I : Economic and Infrastructure		
	Irrigation facilities availability	**IRIGN**
	Road Network and condition	**ROAD**
	Value addition process	**VALUE**
	Market channel	**MARKT**
	Agricultural input availability	**AGINPUT**
	Revenue Cost Ratio	**R/C**
Criteria II : Social Parameters		
	Marketing know how	**MINFO**
	Motivation of Farmers	**MOTIV**
	Cultivation Pattern	**CULTV**
	Labour force	**LABFR**
	Investment capacity	**CAPINV**
Criteria III : Physical Parameters		
	Physical condition	**PHY**
	Erosion Potential	**ERO**
	Crop Intensity	**CRP**
	Risk of urban influence	**URB**

6.3.3 Comparison of criteria for final suitability

Saaty’s theory (1977) on analytical hierarchy process (AHP) is the backbone of the pairwise comparison of criteria and sub-criteria in present study. Large the number of sub-criteria more complicated is the process of suitability assessment (Böhme, 1986). Each criteria and alternatives of the criteria has different influence. According to degree of influence, score values of each of the alternatives are created in the priority order which is subject to analysis in the pair-wise comparison model presented in the methodology (table: 5.6). In this study, factors were rated according to the PRA and evaluation of crop experts. Similar process was also done by Alejandro and Lopez-Blanco (2002) for suitability analysis for potato in Mixico Valley.

Pair-wise comparison is carried out in hierarchical order of the criteria. It begins with the first level i.e. main criteria. If output of main criteria comparison is verified, further comparison process has jumped up into second level which contains sub criteria of the main criteria. While making analysis, an AHP matrix is prepared in the special module developed in Microsoft Office (Excel) which yields final weight of the sub-criteria according to its influence. Weight of the alternatives corresponds with importance of the criteria in the vegetable cultivation in given land area. However it is necessary for the result to be consistent that is determined by Consistency Ratio (CR). CR index is the basis for testing reliability of the comparison result. The result is said to be consistent if CR index is below 0.10, otherwise it is necessary to repeat with revised consideration in AHP matrix for the faithful result. Furthermore, the answers for the questions in pair-wise comparison have close relationship with each other, the questions must be addressed at the same time for more logical feedback. Besides, the final results of weighting are also influenced by the goal of the research as well as the knowledge of the respondent.

First of all, each main criterion has to be fragmented into sub criteria. Each criterion has alternatives, which carries values according to its influences. The nature of AHP method is based on how to analyse intricate problems with number of criteria into simple groups of sub-criteria and set them into priority order without changing their stability and consistency. AHP is an uninterrupted process in which the input data are the results of pairwise comparison based on the response of the research. The AHP has been presented stepwise in the following tables. Each table presents workout of each level. The process of work out, the weights and pairwise comparison first level of main criteria is conducted as in Table 6.3.6.

Table 6.3.6 Pair wise comparison of main criteria in Kathmandu

	ECO	SOC	PHY	Weights
ECONOMIC	1	5	1	0.435
SOCIAL	1/5	1	1/7	0.078
PHYSICAL	2	7	1	0.487
Consistency Ratio (CR) =0.011				

CI: Consistency Index

CR: Consistency Ratio

RI: Random Index

CI = (λmax - n) / (n – 1)

CR = CI / RI

λmax: The maximum eigenvalue

Table 6.3.6 demonstrates that the weights of three main criteria (level 1) for vegetable cultivation in Kathmandu valley by employing AHP method. With consideration of above weights, the physical environmental condition including soil factor claimed to be the most important criteria. Similarly, economic and infrastructural condition is second important criteria where as social attributes are in least important criteria. The CR index is less than 0.011 which verify validity and consistency of so the weights are acceptable and reliable.

1. Economic factors play major role than social factors in selection of the cropping and cropping plot. Infrastructures if laid properly, it stimulate farmers to find particular type of the crops and will create better environment for productions as well.
2. So social factor is less important to a greater degree with compare to economic factors. (table 6.3.6)
3. With physical environment, farmer's response that land physical criteria carries little more importance then infrastructural and economic criteria. This is the condition peculiar to the area like Kathmandu valley with typical physiographic settings.

Pair wise comparison and weights of sub-criteria in second hierarchical level within the main criterion of economy-infrastructure is presented in the appendix table 13 which demonstrates the result of AHP. The higher the weight is, the more important the sub-criterion is, and vice versa. Present research in the periphery of Kathmandu valley show that irrigation is most important factor (weight value 0.322) for vegetable cultivation. Revenue cost ratio is second important sub-criteria. Market channel and road network are next almost equally important criterion. The CR indexes in Table 6.3.4 is 0.027.

Irrigation facility is one of the basic requirements for the cropping but type of the irrigation facilities available influences the decision regarding site selection for the vegetable cropping. In present research irrigation system finds very important and prerequisite for the cultivation if it is moving towards the commercial production from subsistence farming. Therefore suitability determination is based on the irrigation provision. Revenue cost ratio is one of the important factor influence living style of farmers as well as vegetable selection. Well organized vegetable market are not yet been established in all sector of Kathmandu valley. So it is in need to the welfare of farmers. Decent road network connecting all vegetable cultivation pocket areas and market channel are essential for vegetable cultivation development. Process of value addition to the product is important to get good market value. Most of the farmers responding to present research make minor processing like washing and bund making only. So, it seems to carry less value. Agricultural input availability is if compared with other sub criterion, longing of farmers to have fertilizers, manures, improved seeds, etc on time and in required amount is pretty much. Agricultural service centers are scattered within valley but in irregular distance because technical input is equally necessary as materials.

Marketing know-how carries the highest value influencing suitability evaluation process. Based on the weight value presented in the last column, market information, cultivation pattern, capital investment and labour force availability holds weight of 0.440, 0.250, 0.159 and 0.104. Motivation of the farmers is least importance among all sub criteria with weight value 0.048. Appendix 14 offers the result of pairwise comparison of social attributes. Whole process is consistent with CR 0.052.

Expert and the policy makers from the Ministry of Agriculture pointed out that the market policy should be aiming towards the attracting farmers to bring their product for sale. It is necessary for farmers to be informed about ongoing market policies. If farmers are well informed about market and prices of product, they may be motivated with bottom-up approach, it revealed that they are more interested to know about market happening because they can plan their cultivation and farm management according to the market demand. Shortage of labour force was felt around the lower part of the peri-urban area. The matter was more seriously raised because youth are more influenced by urban style of living. They are reluctant in farm related work/profession. The inflow of the seasonal workers from the neighboring district is not permanent solution. Majority of the farmers are small holders, big capital investment is problem. Here motivation is found to the satisfactory level. This weight gained in each individual sub criteria while working with the AHP model, fairly reflects the scenario that was in the field.

Physical environment is the most important criteria, which was further divided into four components of sub criteria affecting vegetable farming in Kathmandu. All of these sub-criteria are related with ongoing processes within the valley. Among them, physical land suitability is very important with weight of 0.635 followed by crop intensity with weight value of 0.201. Erosion intensity and urban encroachment has almost equal value of 0.084 and 0.080 respectively. Consistency ratio is 0.34, which is well below 0.10. Pairwire comparison result of sub-criteria of physical factors is presented in appendix table 15.

Experts and fieldworkers as well as farmers, all of them are well aware of the physical setting and topographic undulations of the Kathmandu valley. Therefore all of them keep physical land suitability as the prime criteria for the judgment of the land. Crop intensity in the field is second important parameter on which most of the land characteristics depends. It might be detrimental if land is cultivated with intensified crops without making proper use of land improvement measures. It also carries value for the consideration. Prevalence of soil erosion hazard threat can be taken into consideration during the land evaluation process. Risk of the urbanization and land encroachment of the cultivated land is ongoing problem in the greater Kathmandu area. But farmers are not much worried on this matter and said that vegetable cultivation does not get much affected with urban expansion. Scattered and small patches of land area can successfully be used for appropriate vegetable cultivation.

Weight of the main criteria and weight of corresponding sub criteria are the basic component of the overall weight of the each individual criterion. Overall weight finally shows its role and possible influence on vegetable crops. Overall weight is computed from multiplication of the weight of main criteria and sub criteria. For example, as shown in the table 6.3.7 weight of the economy criteria i.e. 0.435 is multiplied with weight of its sub-criteria market channel i.e. 0.138 yield overall weight 0.060. This value determines the position of the sub criteria on the importance order. Sum of the overall weight of all criteria involved in calculation will the 1.0.

The overall weight carried by each main criteria and sub a criterion with possible alternatives has been derives through procedure shown in figure 6.3.8. In priority order to make on decision for the vegetable cultivation physical environment plays the most important role. In comparison to other major criteria it draws utmost importance of the farmers and policy makes for the selection of the vegetables.

Table 6.3.7 Calculation and estimation of weights for criterion in Kathmandu valley for vegetable cultivation

Criteria		**Sub criteria**		**Overall Weight**
	W1		W2	Wi= W1 x W2
1. Economy and Infrastructures	0.435	1.1 Market Channel	0.138	0.060
		1.2 Road Network	0.148	0.064
		1.3 Value addition processes availability	0.034	0.015
		1.4 Agricultural input availability	0.096	0.042
		1.5 Irrigation facilities	0.322	0.140
		1.6 Revenue/Cost	0.262	0.114
2. Social Attributes	0.078	1.1 Marketing know-how and information	0.44	0.034
		1.2 Motivation of farmers	0.048	0.004
		1.3 Cultivation pattern	0.25	0.020
		1.4 Labour force Availability	0.104	0.008
		1.5 Capital investment	0.159	0.012
3. Physical and Environmental Factors	0.487	1.1 Physical Condition	0.635	0.309
		1.2 Erosion Hazard potential	0.084	0.041
		1.3 Cropping Intensity	0.201	0.098
		1.4 Urbanization Influences	0.08	0.039

According to AHP methods, weight value has been calculated as 0.487, 0.435 and 0.078 for physical environmental factors, economic parameters and social attributes respectively. Economy and infrastructural criteria is second important and social attributes has least influence over decision making procedure. Altogether there are 15 sub criteria from 3 main criteria assess for the weight value on the basis of its influence over vegetable cultivation. All of them are assessed separately on AHP as developed by Saaty (1977). Last column of the table 6.3.7 presents variable value for each of the sub-criteria which indicate their Overall Weight.

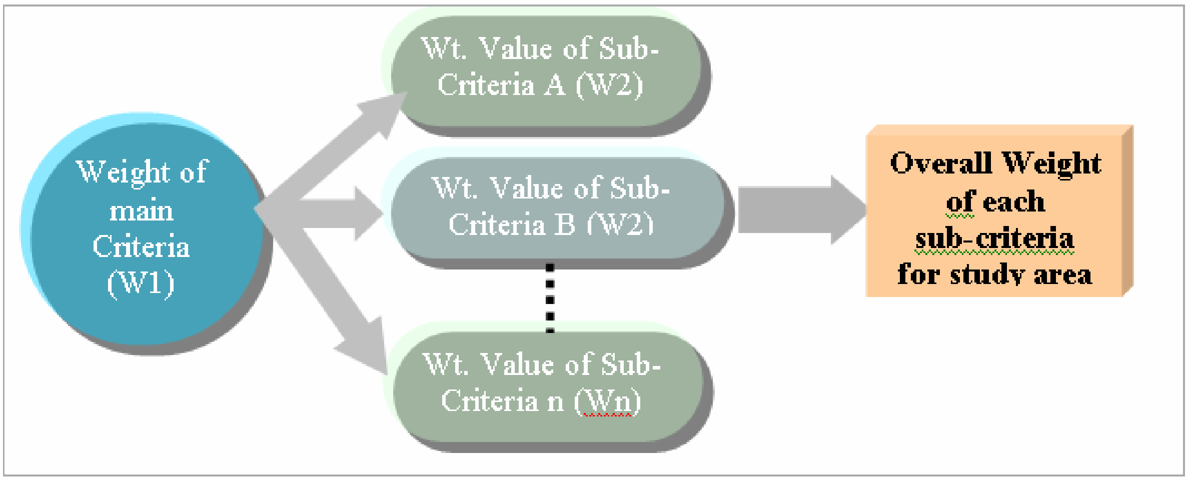


Figure: 6.3.8 Generation of overall weight of criteria and sub criteria through AHP

According to the result of AHP among 15 sub criteria, physical condition of the Kathmandu valley stood first and primary criteria with overall weight value of 0.309. Being unique set up of the Kathmandu valley and its topographic condition, almost all farmers are concerned with soil condition. Therefore, physical land suitability always makes primary criteria for decision making. Similarly irrigation facilities make second important sub-criteria with over all weight of 0.14. Very limited area is facilitated with perennial irrigation system and most of them depend upon rain water irrigation facilities. In the same way revenue/cost ratio is one of the important factors which draws most attention of the commercial farmers. In present research it stood in the third main parameter influencing development of the vegetable production in Kathmandu valley. Larger the cultivation parcel, higher would be the R/C ratio. But in the Kathmandu valley land fragmentation is in continue state, this causes higher intensive labour input, this situation certainly causes to recede R/C ration and decrease net profit. Market channel and road network are inseparable entities for the vegetable crop development. Both have almost similar weight value, 0.06 and 0.064 respectively and stands in 6^{th} and 5^{th} important parameters. Cropping intensity is placed in 4^{th} important value with overall weight value of 0.098.In general land of the Kathmandu valley holds intense cropping system. Present study reveals that motivation of the farmers is least important parameter with weight value of 0.004. Although Kathmandu valley gradually facing labours force shortage in near future, present research identifies it as second least important parameter. Small land parcels and small farmers and huge amount of capital investment are not seen and any parts of valley. Capital investment sub-criterion has overall weight 0.012 indicating slightly influencing role. However farmer’s response shows that they also influence vegetable cultivation to some extent but not severely. Most of the cultivation areas located in the valley periphery is still in cultivation friendly condition. It occupies 8th position in the ranking of the sub-criteria based on its influence for cultivation, which has overall weight 0.041. Weight value of the criteria has been presented in the table below in increasing order of its weight value.

Overall weight of the all the criteria and sub criteria are supposed to be distributed homogenously within study area. Therefore in GIS analysis, all land mapping units have same weight value of particular criteria. It is regarded as the constant for all land unit of study area. These overall weights of criteria are main basis for suitability analysis. Suitability classification is carried out on the basis of Suitability index (Si) value. For particular land mapping unit within study area, situation of the criteria may have different in compared to other land mapping units. Every land mapping units, therefore, have to identify exact status of the criteria. This status is given in the numerical value in the range of 1 to 10. 10 is highly favourable condition and 1 is not at all. The evaluation model is defined using the value of factor rating used to be done by many researchers like, Mongkolsawat et.al. (2002) use value 0.250-1.0 to evaluate S1, 0.1 -0.250 as S2, 0.100 – 0.25 as S3 and less than 0.025 as N. Same author made another numerical classification for grape crop like > 0.2 is S1, 0.1 to 0.2 as S2, 0.01 to 0.1 as S3 and <0.01 as unsuitable. Similarly Kalogiroua (2002) had develop model for land suitability classification in five different scale of score in the range of 100 to 0 where Score 100–98 as S1, 98–85 as S2, 85–65 as S3, 60–40 as N1 and <40 as N2. Therefore, numerical classification is different for different crops in varieties of location. Generation of fact value for any given LMU is very important and crucial. In present study, it is determined through "bottom-up" approach by participatory research appraisal that includes group meeting, questionnaire analysis and brain storming among farmers. The out come is further blended consulting with experts and agricultural extension workers. Field survey of the researcher also gives real time evaluation of the situation because consideration of field condition is mandatory. Weight score of criteria and fact value of alternatives are basic components for the computation of land suitability index.

Then, all information relating to the scores of weighting and fact value of each sub-criterion is transferred to and stored in the land unit database in GIS. The layer of information of scores and fact values of each criterion and sub-criterion is created as thematic maps for conducting the overlaying process. Overlaying the information layers and calculating the suitability level in accordance with the real conditions of Kathmandu valley applies following formula: Si= ΣXi x Wi (Table 6.3.11). Based on the established classification of suitability index (S) Table 5.7 of methodology, the area and suitability level of each land unit for vegetable cultivation in Kathmandu valley is determined. Those land units with general suitability indexes (Si) from 8 to 9 are classified as high level of suitability ($S1_{AHP}$); suitability indexes from 7 to 8 are medium level ($S2_{AHP}$); and less than 7.0 are low level of suitability ($S3_{AHP}$) as shown in the figure 3.6.9. Calculation of suitability index of all 85 LMU is presented in table 6.3.8. Categorisation of non-suitable land area are not incorporated in further lower level it is because when land area is physically unable to allow optimum growth and development of plant, it is worthless making remarks over social and economic attributes. Therefore, non suitable class of land is physically N.

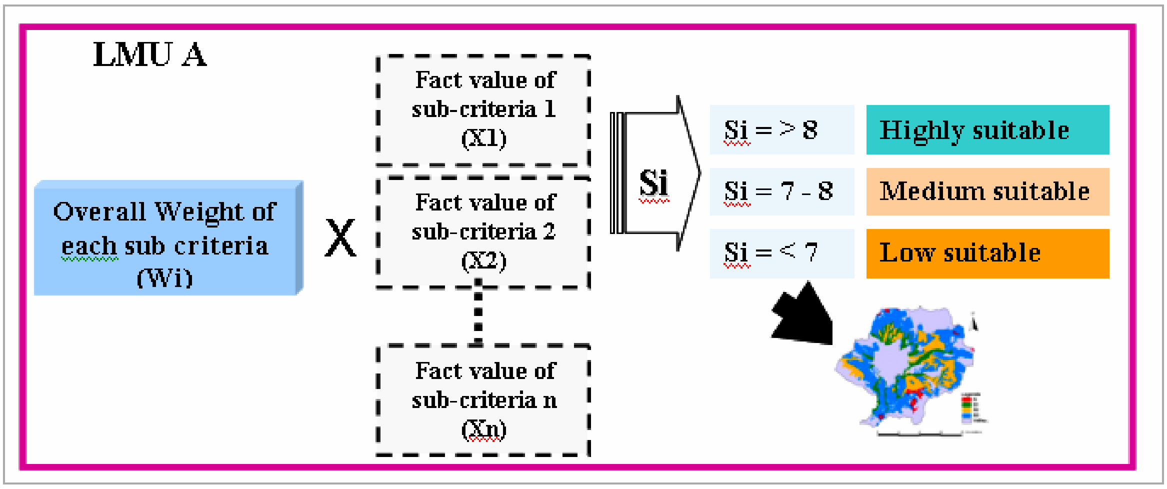


Figure: 6.3.9 Model of suitability rating of individual LMU

Vegetable cultivation in Kathmandu valley plays important role in sustainable agricultural development. According to International Framework for Evaluating Sustainable Land Management (FAO, 1993), FAO instructs that the sustainable evaluation of a land use system requires comprehensive consideration of related criteria, including: economic sustainability, social acceptance and natural sustainability. Depending on the characteristics and development objectives of specific land use types or crops, these criteria have different significance and priority weights. This causes certain difficulties for land users to decide which crops or land use types are suitable. The results of land suitability evaluation for land utilization type of specific vegetable varieties in study area involve AHP analysis method, this is an approach to deal with multi-criteria problems to identify the suitability level of each land unit and propose sustainable agricultural land use orientations in the future.

Table: 6.3.8 Suitability indexes of all the criteria for multi-criteria land suitability evaluation.

LU ID	AREA (Ha)	Si= ΣXi x Wi										Index (Si)	Suitability So-eco
		Irign	road	value	Markt	Aginp	n1	n2	n	Crop	Urb		
1	13.0	0.98	0.32	0.11	0.36	0.29				0.69	0.35	4.9	N
2	3541.7	0.98	0.45	0.14	0.42	0.29				0.78	0.35	6.6	S3
3	572.3	1.12	0.45	0.12	0.48	0.34				0.78	0.31	6.7	S3
4	338.3	0.70	0.38	0.11	0.36	0.29				0.69	0.35	4.6	N

Detail of all land mapping units are presented in the table in appendix table 16

Result obtain from the physical land suitability evaluation and multi-criteria analysis of all the criteria further blend in the LIS database for the estimation of the final result of land suitability. Each of the attributive information of the study area is designed to form separate layer for production of thematic layer. All of them are subjected to overlay in GIS environment for estimation of final results of multi-criteria land suitability evaluation of Kathmandu valley for vegetable crop production. The attributive information from 15 sub-criteria of 3 main criteria is overlaid and used for reckoning suitability index (Si) for each and every land mapping units within study area.

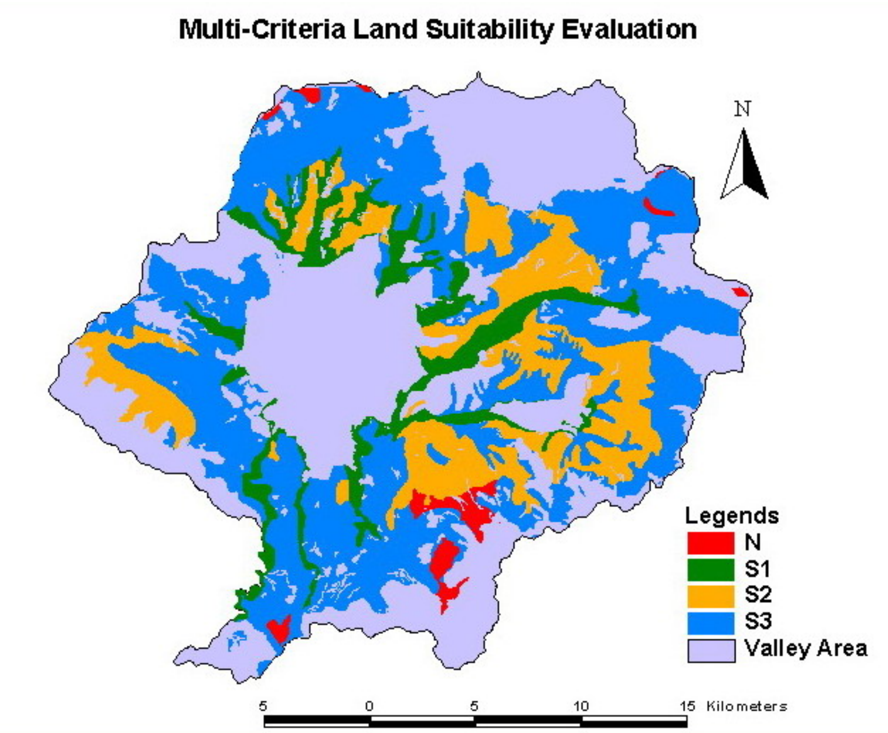


Figure: 6.3.10 Multicriteria land suitability evaluation of the Kathmandu for vegetable cultivation

Figure 6.3.10 is the GIS map of Kathmandu valley showing distribution of the different land unit in their own suitability classes. Allocation of the information regarding fact value for each of the alternatives is basically based on bottom up approach which is giving real time situation estimation

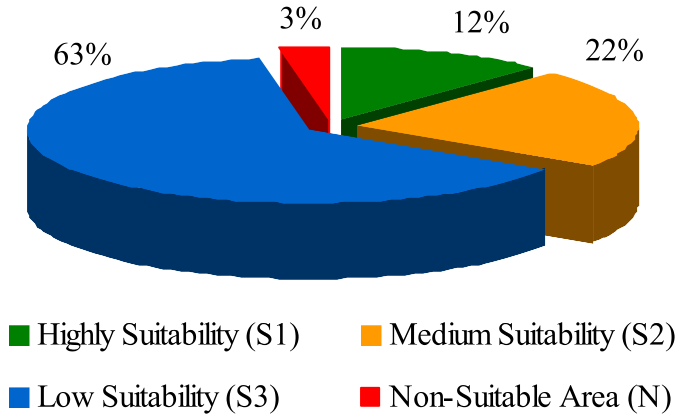


Fig: 6.3.11 Percentage of land area for different suitability evaluation

From the analysis it appeared that in Kathmandu valley severity of the limitation has resulted into differences in suitability classes. Present analysis shows that only single land units with an area of 2834.2ha falls under the S1 category. This is purely peri-urban area with lowland alluvial plains with good drainage soil. Still the area is variously used for the vegetable cultivation. Second category of medium suitability (S2) is distributed into 24 land mapping units cumulatively accounting for 22% to total land area. More than half the total land area is belongs under low suitability classes i.e. S3 class (figure: 6.3.11). Number of land mapping units for this category is 53 and is distributed through the inner periphery of valley. Although socio-economic condition and infrastructural availability are in normal condition some land mapping units have unsuitable type of land settings. Therefore, in present study altogether 7 land units with total area of 664ha is falls under unsuitable area for vegetable cultivation purpose. Table 6.3.9 provides summary of land units with suitability ratings of study area.

Table: 6.3.9 Details of the Multi-criteria land suitability evaluation of Kathmandu Valley for vegetable crops.

Suitability Ratings	Counts	Area (ha)	Area (%)	Land Units
Highly Suitability (S1)	1	2834.2	12.05	10
Medium Suitability (S2)	24	5185	22.05	8, 11, 13, 17, 18, 19, 23, 24, 27, 31, 34, 37, 41, 48, 49, 53, 58, 60, 63, 67, 68, 70, 74, and 75
Low Suitability (S3)	53	14836	63.08	2, 3, 6, 7, 9, 12, 14, 16, 20, 22, 25, 26, 28, 29, 30, 32, 33, 35, 36, 38, 39, 40, 42, 43, 44, 45, 47, 50, 51, 52, 54, 55, 56, 57, 59, 61, 62, 64, 65, 66, 69, 71, 72, 73, 76, 77, 78, 79, 80, 81, 82, 83 and 84
Non-Suitable (N)	7	664	2.82	1, 4, 5, 15, 21, 46 and 85
Total	85	23519.2	100.00	

6.3.4 Discussion

Application of the multi-criteria land suitability evaluation based on the FAO method has been adopted in the context of hilly area with appropriate modification. Unlike some of the literatures (choung, 2007) physical land parameters are identified as most important criteria. It is very natural because the case would be true only in the area like Kathmandu valley with undulating uplands with many limitations. Urban sprawl is also continuing because of topographic setting and centre for economic. A second important criterion is economic-infrastructure and social attributes has least weight, so it is third important criteria. Multi-criteria analysis was carried out through MCH process, and among 15 sub criteria, physical land parameters and irrigation facilities and revenue/cost ratio are calculated as first, second and third important sub-criteria respectively which are influencing suitability ratings of land area accordingly. Among other sub-criteria most of the sub criteria of economic-infrastructure are decisive in the processes like market channel and road network. AHP process to calculate weight for the importance identification of the sub-criteria, consistent ratio (CR) has been maintained for reliability because CR has to be below 0.10 otherwise the calculation is taken as an inconsistent.

An important advantage of GIS is the ability to update current ratings easily when new or better information becomes available (Pradhan & Perera, 2005) and the ability to obtain output from the improved model. A new map can be generated in a relatively short time with less effort and lower cost than for additions to files on paper, manual planimetry, and conventional map updating (Hossain et.al., 2007).

General impression from the research is drawn that motivation of the rural people towards cultivation is praiseworthy in comparison to urban dwellers. Basic factors for making changes in the suitability ratings of the land area are availability of the irrigation sources and market related knowledge of the farmers. Physical land characteristics like soil fertility is one of the prevalent factors which make most of the land mapping unit falls under lower suitability class. So availability of the agricultural inputs in the uplands of Kathmandu valley seems important. If correction is done over problems identified in present study, majority of land area can be rated into highly suitable class. Farmers have to be considered as core factors for the motivation. Awareness and motivation will develop level of agricultural practices and information about market know-how to the farmers. If farmers are motivated to make use of output this study, empowerment of vegetable growers can be done.

Land fragmentation is another factor to effect land use discussion. Fragmentation results in small size of land holdings. Smaller the size of land, intensive input applied keeping production constant (Upreti and Upreti, 2002). So, R/C ration would be affected. Urban sprawl in Kathmandu is one of the burning problems for the urban vegetable growers because present trend of urbanization resulting into conversion of agricultural land into small fragments and sell it for the purpose of construction. Still half the total vegetable growers are adopting traditional way of cultivation which doesn’t apply any measures to control erosion. This is related to cultivation pattern for specific crop and physical land setting. Therefore majority of the respondent are reluctant to know more about soil conservation measures. However this issue was main theme of discussion on seminar with experts.

7 GENERAL DISCUSSION

Multi-criteria land suitability evaluation in this study uses physical and environmental parameters, social attributes and economic indicator as necessary factors for best possible outcome consulting both with farmers and experts (Cools et al. 2003). Spatial information like maps and land related attributive characteristics are incorporated into GIS based data of land suitability evaluation as a system. Use of social and economic parameters through AHP analysis provides reflection of real situation of study area. GIS technique along with AHP used for the land suitability evaluation improves efficacy of the outputs of the evaluation.

Agricultural land use planning, resources management decision making in Nepal required consideration of land ownership and land tenure policy. Lack of access to agricultural land is probably the main contributor to rural poverty but poor quality of land, such as in the rainfed areas of the Hindu Kush (Mountain) region, has become a major obstacle to agricultural growth and alleviation of poverty (Khan, 2000). Land degradation aggravates poverty but equally poor agricultural practices induced by poverty exacerbate land degradation creating a downward spiral of human and environmental exhaustion. So Kathmandu valley coincides with the situations mentioned above. The reasons for uncontrolled urban growth are the massive in-migration and natural growth in the Kathmandu valley. There are urban plan and policy guidelines to manage the urban growth in the country but these are not implemented properly at the city level (Pradhan & Perera, 2005). Transformation of agricultural land to non agricultural purpose is growing problem in Kathmandu valley, and agricultural land is getting depleted mostly in the core area of valley. Therefore, result of this study can lay one milestone for the stakeholder to know potentiality of the land for effective land use and land management.

Under the Agriculture Perspective Plan(APP), priority has been given to soil fertility research and extension particularly through integrated plant nutrient management systems (IPNMS) that incorporate both organic and inorganic fertilisers (MoA, 2005). Due to inadequate attention to land ownership issues and tenure arrangements the future impacts on soil fertility and expansion of intensive farming in hill and mountain areas will be effected. (Blaikie and Sadeque, 2000). Therefore guidance must come from the policy statements and translated into operational plans that help implementation of land management activities.

The existing policies need to be simplified, harmonised and brought into line with other policies.

Application of information technology in this area is inevitable. However it is not gaining enough attention of planners and policy makers for land management in Kathmandu valley. Present research work indicated the need of all round information exploration for development of vegetable farming at the community level. Output of the scientific result should aim to enhance the sustainability of natural resources for livelihood of the local people concerned. Therefore social and economic attribute together with land quality information in present work are combined to have useful, comprehensive, systematic, easy-to-use and easy-to-update information system. This type of study from national level to village committee level is very essential to enhance vegetable farming system in particular and overall agriculture in general is needed to uplift economic level of local farmers. Given the continued degradation of natural resources, appropriate natural resource management policy decisions are arguably the most important among various policies implemented in developing countries (Babu and Roe, 2000).

Soil fertility and nutrient availability in soil of Kathmandu demands reasonably external input. Soil fertility capability classification can be performed through GIS, after LIS generation is complete where external fertility status of soil is expressed. Fertilizer application has to be coupled with use of all natural and man made sources of plant nutrients so as to increase crop productivity in an efficient and environmentally benign manner, without diminishing the capacity of the soil to be productive for present and future generation (Gruhn et.al., 1995). Fertilizer nutrient applications are necessary to maintain soil fertility and sustain agriculture over long time, however over application is simply wasteful. Low use of fertilizer reduces fertility of soil and it also increases soil degradation through nutrient mining (World Bank, 1992)

Vegetable sector is one of the important components of Nepalese agriculture where diversity in vegetable cropping brought about by different agro-ecological regions of the country. Nepal falls under category of low human development index country. High economic growth rate is expected in the long term which is necessarily contributed by National agricultural Plan. It simply aiming to

a) Increase on vegetable consumption to support on nutritional security of the people
b) Emphasis on intensive farming rather than in extension of the land area
c) Diversify vegetable farming according to agro-ecological zones of Nepal
d) Put emphasis on commercialization of vegetable cultivation

Kathmandu valley is popularly known for its contribution on vegetable production. However in the recent decade, population explosion, ecological degradation in the hills and the rapid degradation in the quality of the urban environment, including riverine ecology, have raised concerns. The growth rate of the urban population is higher than the rural population. Topographic setting causes to have great variation in climatic condition between the valley basin and the surrounding hill ridge. Kathmandu valley possesses suitable physical environments for vegetable production. Nowadays identification of the land area matching specific vegetable varieties is becoming major concern. Although total land area has potentiality to supply about 72% of total demand of vegetables, it is supplying only about one tenth of the total consumption. Therefore relevance of this type of research can make sincere contribution to lead farmers towards economic benefits and also maintains agro-ecological prosperity. While making suitability analysis, it is very important to incorporate aspiration of the farmers to motivate them on the mainstream of peri-ruban vegetable cultivation. Along with physical and land attributes, importance of the social attributes to the vegetable crop development and overall agricultural enhancement in Kathmandu valley has achieved by present research. Especially broken and undulating topographic land area needs to be segregated and specially allocated for the development of vegetable self sufficiency. If result of the present study is followed at least within Kathmandu valley, this will contributes to the greater extent to National Agricultural Plan.

Indigenous knowledge of farmers is one of the major factors contributing to conservation of agrobiodiversity. Berkes et.al. (1995) describe that an important element of indigenous knowledge is its foundation in several years of experience and observation of farmers on particular species and their interaction with ecosystems. If land is utilized with its full capacity to grow potential cash crops like seasonal vegetable compatible with local farming system, it helps on reduce poverty and enhance land improvement process. Farmers make efforts to maintain and conserve the diversity of living organisms and their habitat through the particular farming systems of their area. Changing in farming system over time could bring counter productive result. Conservation of indigenous species with improved method of cultivation incorporating in existing farming system of Kathmandu valley can help conservation of agro-biodiversity. At the same time increasing population pressure, rampant poverty and environmental degradation in Nepal are posing severe threats to floral and faunal diversity in Nepal (Upreti and Upreti 2002).

Vegetable farming in chronological basis in planned way makes optimum utilisation of land capacity. Result of multi-criteria evaluation of land will determined investment requirement. If area comprises with smaller holdings should only have intensive cropping which require high investment.

Suitability index is one of the best measures for the decision making for land selection. The result of present study suggest that land area with suitability index above 6.0 (Si >6.0) can be used by user for vegetable farming. If Si index is below 6.0, it possess with different degree of limitation, some of which are related with social and economic limitation. Numerical categorisation for the suitability index will more precisely site specific (Kalogiroua, 2002) however the range more often is in the scale of 1 to 10. Such area cannot be allocated for the cultivation purpose. The investment requirement for such area is very high depending upon degree of limitation. Those areas can be used for alternative purpose, like forestry or recreational or may be building up area. If minor soil related limitations are there, gradual process can also be recommended to correct limitation in the long term basis.

If massive land area is selected for the vegetable cultivation in commercial basis, multi-criteria suitability analysis is only alternative to assist for decision making process. Infrastructural criteria can have big role however, small area cultivation for domestic purpose can be carried out as a test plot. Looking at the economic status of Nepal, identification of suitable land area for any kind of vegetable cultivation ensure food security and uplift nutritional security within country. If fertility management of the soil is done as indicated by present study, it will definitely enhance productivity. More production can reduce market price of the vegetable commodity which can be purchased by lower class population. This certainly helps on ensuring nutritional security of resource poor household. Hence, the model of suitability analysis is decent method to be applied for the extension of the cultivation area and selection of the variety of vegetable crop for the enhancement of economic status of farmers.

It is the responsibility of land users to make clear selection of the area to be used for cultivation, which further be evaluated through multi-criteria analysis using AHP. GIS being one of the powerful tools, efficacy of the evaluation process will be maintained. Non spatial parameters can also be analysed in the spatial basis to help making decision process easier

Response to Research Questions

The findings of this study are able to address the research query set during hypothesis setting. The success of the research lies in level of satisfactory answer put forward by research result.

Query 1: *How is the vegetable cultivation practices and land use condition in Kathmandu Valley?*

Introduction of study area in previous chapter provides baseline data for the selection of evaluating criteria. Following conclusion are made after carrying out descriptive analysis of the study area. The climate conditions of the study area like precipitation, temperature, humidity, wind speed, etc. supports development of wide range of vegetable crops. This is a very big advantage which can offer high productivity. However, irregular annual rainfall distribution, longer drought period would result in water shortage condition which has to be mitigated with irrigation arrangements. Clear seasonal gradient is helping for growth of specific crops but off seasonal vegetable production in plastic tunnel and temporary green house is also popularly adopting by the farmers. In addition, altitudinal gradient demands mixed type horticultural practices like agro-forestry which is in practice in peripheral slop upland area. The terrain of the valley is very complicated. Mountainous terrain with various slope gradients is difficult for designing fields and growing vegetable crops. This is very potential to cause erosion and severe soil impoverishment and deterioration if cultivation doesn’t consider right methods. Although water bodies in the valley are evenly distributed, they are not able to sufficiently supply the water demand for domestic and irrigation purpose. Therefore, easy and accessible alternatives for irrigation system are necessary to clear severe limitation for suitable land allocation.

It is very discouraging situation for extension of agricultural land, at present situation, it can only be done with expense of valuable forest area. However this activity causes gradual corrosion in biodiversity. Rather agricultural land area is constantly been sprawl with settlement extension.

The socio-economic status of the farmers in study area is up to average level. There are good network of rural road system, but poor irrigation possibilities. There is couple of well organized markets places with good marketing channel. Field-to-Sell system of marketing is popularly established in Kathmandu valley, where farmers bring vegetables directly from farm and sell them directly to the consumer. Complicated marketing network involving series of middleman is unpopular to the small producers.

Because of topographic constrains, larger machines and tractors cannot be used. Small holdings of agricultural land are managed with hand used simple agricultural tools. Availability of agricultural labour force in some area limits cultivation activities. Education and technical know-how is limited among majority of the farming population. Most of them are manual workers and are champion in traditional ways of farming. In the same way farmers from low income group have incapable of enough capital investment which affects agricultural activities during sowing period. Agricultural service centers are not evenly distributed along study area this limits easy and frequent consultation to every farmer as and when they need it.

Of total area of 58,369ha, only 23,519.3ha of land is presently available for agricultural activities. Research reveal that only about 33% of present total agricultural land used for vegetable cultivation purpose, rest area is permanently used for the traditional cereal crops cultivation. From the analysis of soil characteristics, soil in the valley has potentiality to support diverse vegetable crops. Decrease in organic matter (OM) content and low soil fertility is prevalent limitations of study area. Only about 3% area holding very low fertility status, rest belongs to medium fertility status. The level of soil fertility can be ranked through assessment of Potassium>Carbon>Nitrogen>Phosphorus in soil. This parameters is temporary and be corrected with necessary input. With wise and appropriate agricultural input, they can bring about long-term effect to support vegetable crops.

Lack of a comprehensive land use policy base on the land capability is one of the big problems. Rice-wheat and maize-mustard is most common agricultural land use pattern. But since a decade, wheat and mustard in both pattern of cultivation is gradually replaced by vegetable. Some of the land mapping units in eastern periphery of valley, vegetable crops is only cultivated round the year. Vegetable cultivation brings diversity on cultivation and higher quick turn over, which bring about high and stable economic benefits. Market oriented cultivation derive farmers to make decision on selection of vegetable varieties. Therefore, suitability assessment will have marked benefits in this regard.

Query 2: *What are the promising vegetables in the existing land, climates, social-economic and infrastructural conditions study area?*

During period of investigation, three main group of vegetable found to be promising in existing condition of Kathmandu valley. First group of Cole crops which includes cauliflower and cabbage. Local varieties of cauliflower are one of the oldest cultivating species and popularly consumed by people. Due to the climatic severity, such vegetables can only be cultivated on specific season. These vegetable provides good economic return to the growers. Similarly, among root crop, raddish and carrot are promising ones. Soil of upland with higher sand content is better option. Slope and rough topographic land area is also successfully be used. Low economic input and high and fast return would help growers uplift their economic condition. Low land of the valley basin is popularly used for the potato cultivation. Most of the lowland areas are supplied with perennial water sources which makes them easy for irrigation. Third category includes fruit and leafy vegetable like tomato, egeplants (brinjal), beans, and so on. Cultivation of such vegetables is diversified in season and quantity. Local food habit, tradition and social structure are seen as driving forces for vegetable growers in peri-urban area of Kathmandu valley. Market demand is very often determined by food habit and tradition. Therefore, farmers are selecting vegetables which require less value addition procedure and high demand commodity for commercial purpose. Couliflowers, raddish and potatoes are most used and largely cultivated in Kathmandu valley. Climatic condition analysis shows that condition is appropriate for vegetable and seasons.

Query 3: *How does land information system (LIS) play role in suitability evaluation?*

Land information system (LIS) is the back bone of the land suitability analysis through GIS application. For the purpose of present research the land suitability evaluation. Different information sources were used for soils and land information collection where the real conditions of the study area were also consided. This study has identified major factors to be contributed to establish land unit map, including soil unit types, soil slope level, soil layer depth, soil texture, etc as spatial information. Database is entered in the GIS environment and separate thematic layers are produced. Each of the thematic maps with information on all 85 land mapping units is for the generation of land suitability map for vegetable crops in Kathmandu Valley. Using LIS a database system is created with help of the GIS software, allowing users to access, edit, overlay and analysis to establish a new map that meets the requirements of the study. Moreover, LIS helps to create new information, saving time searching for fundamental figures from the very beginning. The land use consultancy and land suitability assessment for agricultural crops, sustainable land use planning and land allocation are therefore easier, which directly benefits the users. Existing land information system and database of land units managed and stored in the GIS can be updated and be used for land suitability assessment of different agriculture crops and land management.

Besides this area for the suitability analysis can be brought into any boundary level from Kathmandu valley to district level and also in the village development committee (VDC) level. Land information system is necessary and usefulness village level because local authorities always prepare policies in micro-level targeting poor farmer with small holdings. Land information system prepared in this study for Kathmandu valley can be use for the other non agricultural purpose. Agroforestry development, land use planning and land management. Therefore, suitability evaluation of the land in Kathmandu can be done for many other crops and sustainable land management as well. Erosion hazard distribution map can also be prepared with some more subsidiary data. This further helps on handling of agricultural land with appropriate technology and crops. This makes further easy and accessible to update and apply LIS database for effective result.

Query 4: *How is physical land suitability assessment resulted?*

Physical land suitability evaluation involves land and climatic attributes only. Among them soil parameter are important parameters that makes decisive role on physical land suitability analysis. In physical land suitability the high suitability level (S1) does not exist in any land units but in potential land suitability, S1 category was found in some 17% land area belonging to 11 land mapping units. Similarly, 30% (7273.14ha) of Kathmandu valley shows second category S2 level where as in potential suitability, it extends up to 38% (9085.10ha) of land area. Third category (S3) was most prevalent in the suitability class. It account for 33% land mass of study area belongs to current suitability which is improved into 38% in potential suitability. Among all these major limiting factor for current suitability is soil fertility. Here in this case regular input can improves the soil condition. In potential suitability, land slope is major limiting factor, which can't be corrected easily unless improved technology is applied for example Sloping Agricultural Land Technology (SALT).

Result concluded that suitability of all the land units are consisting of land quality with limitations of certain degree. These limitations are dominant ones which are very difficult to transform, including: unsuitable soil types, soil texture, steep slope and so on. Some limitations can have marked effects on suitability rating but can easily be improved, such limitation are called as ordinary limitation. For example, low soil fertility (pH, OM, N, P, and K). From the suitability level of current physical land, analysis and evaluation of potential suitability level of land units is done. Technical and economic measures are considered to make correction on the limitations, so that the result of potential land suitability is achieved. After recommended remedial activities, suitability ratings of land units get improved. The potential physical land suitability is then brought to the second stage of suitability analysis, together with the socioeconomic and infrastructural conditions. In later cases, area with physical suitability level of S1, S2 and S3 are taken into consideration; where as non-suitable land (N) is not considered for further evaluation.

Query 5: *What are the criteria for suitability evaluation and how does multi-criteria land suitability evaluation classify land in different suitability ratings?*

For vegetable crop development in Kathmandu valley, in present research, land suitability evaluation has been carried out based on three main criteria: namely physical environmental conditions, social parameters and economy and infrastructure conditions. Total assessment process was laid out in two ways: first, evaluating the physical land suitability level where land characteristics are evaluated and Second is outcome of physical land suitability evaluation in combination with social parameters and economic-infrastructure condition of study area. Sub-criteria of these three sectors are blended for multi-criteria analysis making use of AHP procedure. Results of Multi-criteria land suitability evaluation has been presented in chapter 6.3.

In Multi-criteria land suitability assessment for vegetable crops in Kathmandu valley, first of all three main criteria and 15 sub-criteria was set as mention above. Through pair-wise comparison, among them physical land criteria was computed as most important characteristics, because it has highest weight value. This is very natural result to the area like Kathmandu valley. Second important parameter belong to the economic and infrastructural parameters and social indicator stood third criteria with lowest weight. The result mostly based on the "bottom up" approach.

Among three main criteria most important physical and environmental criteria has further fragmented into 4 sub criteria. Physical condition (PHY), erosion hazard potential (ERO), cropping intensity (CRP) and urbanization influences (URB) are sub criteria of physical environment. Importance order generated as PHY, CRP, ERO and URB. Similarly, economy-infrastructure criterion has six sub-criteria, namely market channel (MARKT), irrigation (IRRIGN), Road network (ROAD), Value addition Process (VALUE), Agricultural input availability (AGINPUT) and revenue cost ratio (R/C). In importance analysis, an irrigation facility is rated as prime important parameter followed by revenue cost ratio. Road network falls in third important criteria. Value addition procedure is least important one. Social criteria has 5 sub criteria namely marketing know how (MINIFO), motivation of farmers (MOTIV), cultivation pattern (CULTV), labour force availability (LABER) and investment capacity (CAPINV) rural road systems. In important rating through pairwise comparison in AHP process, marketing know-how and cultivation pattern are important ones.

In next phase of analysis, all of these 15 sub criteria belongs of 3 main criteria are analysed through AHP for the multi-criteria evaluation of the land area. In this case physical land condition has highest weight value among 15 sub-criteria. It is followed by irrigation sub-criteria of economic infrastructural criteria. Revenue cost ratio, cropping intensity, road network, market channel are group of most important criteria. All these together makes influence on overall suitability ratings. While making computation the result has to be consistent, for which during pair wise comparison, consistent ratio (CR) index should be below 0.10. Majority of social attributes are falling under less important criteria which make less contribution on multi-criteria land suitability evaluation.

After these entire endeavors, it comes into final suitability evaluation with inclusion of all the criteria and sub criteria. The result of suitability assessment based on the above criteria and sub-criteria show that there is only one land mapping unit falls under high level of suitability (S1) for vegetable cultivation in Kathmandu valley. Most of the area with 63% (14836ha) categorized as low suitability (S3) and 5185ha accounting for 22.05% of total agricultural and area is categorized as medium suitability (S2) class. Still 2.82% falls under permanently unsuitable category.

Query 6: *Will suitability evaluation help Kathmandu valley attain vegetable self-sufficiency?*

Kathmandu valley is experiencing mishandling of the prime agricultural land for off farm purposes. So, the major problem in the valley regarding land use is loss of prime agricultural land and depletion of forest resources in expense of built up area extension. In Kathmandu valley two systems of vegetable production are in practice, namely at subsistence and at semi-commercial level. Land suitability evaluation stimulates farmers to transform from non commercial level to purely commercial level. More than one third farmers are cultivating vegetable considering market demand and social causes. They do not consider land capability. Even in the existing condition, in total contribution is 23% total vegetable consumption of the valley. If it is wisely managed, it would be sufficient to rise up to 73% of existing consumption. Therefore, if cultivation of the vegetable crop in Kathmandu valley considers findings of Multi-criteria land suitability evaluation, it has greater contribution other way round. Sustainable use of the land and rational use of agricultural inputs reduces economic burden of the farmers. Intensification of agriculture is also possible through identification of the suitable land area. For suitability assessment, development of the LIS is mandatory; therefore land management for alternative crops can be done on needy basis.

***Query** 7: Who are the main beneficiary of present research?*

Among four stakeholders i.e. farmers, environmentalist, urban planner and governmental officers, farmers is the crux to make use of present research out put. Research process could be the matters of interest for further extension to the urban planners and extension officers. Identification of the capability of fertility status of the each parcel of land is concern of grower. Limitation pointed out by present research is major concern of the vegetable growers. Therefore, present research includes dimension from all the sectors, of society and environment, suitability evaluation will benefits to those who is directly use land for the purpose of vegetable growing. At the same time, urban planners are also having peer view on result so that agricultural land with high degree of suitability can keep allocated for agricultural priority in planning process. Government officers are concern more to formulate the Agricultural Perspective Plan (APP). Result of the suitability evaluation can contribute to greater extent land management and planning process for particular area. Therefore, all the stakeholders are supposed to exploit outcome of present research result.

During study process, research is encountered with number of problems. Social taboo, internal labour exchange system, mal functioning of the agriculture service center and under skilled human resources, etc. are prevalent issues to be corrected. Probability of intensive vegetable farm development still has hurdles like capacity of farmers to make investment and availability of easy and accessible labour force. Post harvest processing would also increase farmers capacity of enhance production. These types of the problems, although not the spatial attributes, need to be addressed timely. These can play decent role in improvement of the suitability evaluation of any piece of land mapping unit in study area. Therefore, result of present research would be the interest of all stakeholders including farm people to policy makers.

8 CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

Study area located in Kathmandu valley, capital of Nepal. Agricultural land area is constantly transforming into non-agriculture. Valley dwellers are depending on outside source for vegetable. It is very essential to understand land capacity to support appropriate vegetable cultivation. Land suitability evaluation is one of the best alternatives and multi-criteria land evaluation further gives best suitability classification considering wide range of multi-disciplinary alternatives. It also identifies land limitation and offers possible land management measures. Methodology for present analysis presented in chapter 5 described the land suitability evaluation process based on FAO framework is appropriately amended for the case of Kathmandu valley. Analysis has been carried out developing LIS and processing was done using GIS-based the multi-criteria evaluation approach. So, two sided important application of present research is development of the methodology which includes multi-dimensional approach. The generation of specific numerical order for suitability evaluation is one of the major out come for the Kathmandu valley's horticultural development. This model of land evaluation can successfully used in other similar valleys of Nepal.

First and foremost important is development of LIS for any piece of land to be evaluated for any kind of cultivation. For land inventory system updating require sufficient, consistent and continuous data sources to analyse current status, to predict changing trends land resources deterioration, and to assess land suitability evaluation for crops precisely. Emphasis was given to develop LIS up to the local village level in Nepalese context. In present context, one of the main hurdles is lack of information dissemination and attitude not work under information sharing culture (Tuladhar et.al. 2004). Information collection was basically done through bottom-up procedure, so that real circumstances are incorporated into final result. Such collected information has to put before expert opinion for top-down approach. Here the involvement of local farmers, land users, and specialists for comprehensive evaluation is mandatory. The study has also indicated that GIS is a useful supporting tool in integrating socio-economic and environmental data the comprehensive LIS databases could provide needed details of information to stakeholders (Oli, 2001). Second important outcome of the research is the evaluation of land area with particular identification of strength and limitation for horticultural crops. So farmers are advised to make use of research result to cultivate vegetable according to its potentiality. Site specific classification in order of suitability is main interest of vegetable growers for further vegetable crop development.

8.2 Recommendations

It is urgently recommended to disseminate result of present research in Kathmandu valley because identification of very suitable and promising vegetable growing area might be protected from the urban sprawl. It is also recommended to make vegetable sector development plan for Kathmandu including Nepal because vegetable sector is one of the important components of Nepalese agriculture, where diversity in vegetable crop brought about by the diversity in agro-ecological zones. It is necessary to enhance the fresh vegetable production and productivity for

a. Nutritional supplement
b. Strengthening local agro-business in the rural area
c. Economic benefits to the poor and under privileged farmers.
d. Contribution to the environmental conservation

Very important is the result of suitability evaluation must be brought into the reach of vegetable growers. Multidimensional approach of present research has put a number of recommendation forward to the stakeholders are as follows.

1. It is important to create the soil databases and land information system, including soil types, soil fertility, terrain, current land use status, climate, slope, vegetation cover, soil erosion, land unit map. The database system will be created on the GIS software, allowing users to access, edit, up-to-date, overlay and analysis to create a new map which meets the requirements of the study problem. Application of other information sources like remote sensing images, Global Positioning System (GPS), etc should be encourage because it will help on bringing real time change in land use and management strategy.
2. Further study should be carried out to construct a complete and official database with close links among different information sources of natural environment, economy conditions, infrastructure, and the society.
3. The model of present research work must be applied to determine land evaluation for other agricultural crops as well. Fundamental aspect of the research is feasible in context of Nepal however, flexibility on selection of the criteria and sub-criteria for different crops and in other geographical locations should be offered.

During the period of data collection, researcher was encountered with urgent necessity of soil improvement and soil protection for sustainable agricultural productivity. Soil management measure is also necessary tool for the farmers to harness potentiality of the land are in Kathmandu valley because of reduced fertility; especially the level of potassium availability, organic carbon, total nitrogen, and phosphorus availability. Regular application of lime is also recommended. Care of top soil is still not up to standard. In the same way cultivation in the slop land is still in practice but it is not recommend, however conversion into terraced land with recent technology will be appreciated.

4. Some of the problem of vegetable farming sector like lack of the human resources, lack of institutional reform, insufficient budget, lack of infrastructural reforms and tough national situation has to be tackled with enhanced vegetable planning through suitable area allocation for specific vegetable. Therefore, suitability assessment has to be implemented in every sector of agricultural development.
5. To emphasize on generation of competitive capability of the farmers from the national level it is necessary to put emphasis on enhancement of qualified field level technical man power so that effective services can be delivered promptly.
6. Input subsidy policy, improved irrigation facilities, quality agricultural inputs, development of market support system, capital investment facilities are very necessary steps to be implemented. Then after suitability assessment will be implemented in that area.

Finally the out come of the research has to be disseminated among local vegetable growers and make them understand about capacity and limitation in range of suitability of their farm holding. Land parcel use potential, limitations prevail and management measure should clearly be conveyed to land users, so that the real use of research will be seen.

9 REFERENCES

Alejandro Ceballos-Silva, Jorge Lopez-Blanco, 2002. Delineation of suitable areas for crops using a Multi-Criteria Evaluation approach and land use/cover mapping: a case study in Central Mexico, Agricultural Systems *77* (2002) 117–136

Anonymous, 2001. Periurban Horticulture of Kathmandu Valley, internet publication, 2001.

APO, 2002. Urban Fringe Agriculture, Asian Productivity Organization, Tokyo, Japan.

Arsanti Idha Widi, 2008. Evaluation of Vegetable Farming Systems in Upland Areas of Java and Sumatra, Indonesia. A PhD dissertation submitted to Humboldt-Universität zu Berlin, Germany

Asian Vegetable Research and Development Center. 1990. Vegetable Production Training Manual. Tainan, Taiwan, pp. 154-252.

Astin, M. P and J. J. Basinsky, 1978. Biophysical survey techniques: CSIRO, Australia: 62-67

Babu, S. and V. Roe, 2000. Capacity Strengthening in Environmental and Natural Resource Policy Analysis: Meeting the Changing Needs. Journal of Environmental Management *58(July):* 4.

Bacic, I. L. Z (2003) Demand-driven land evaluation with case studies in Santa Catarina, Brazil, *ITC Dissertation number 105*, ITC, Enschede, Netherland: 25.

Banai, R., 1993. Fuzziness in geographic information systems - contributions from the analytic hierarchy process. International Journal of Geographical Information Systems, *Vol. 7*: 315-329.

Baniya, N., 1995. Ecological Study of Shivapuri Forest, M. Sc. Dissertation submitted to CDB, Tribhuvan University, Kathmandu, Nepal.

Barredo, C. J. I., 1996. Sistemas de Informacio´ n Geogra´ fica y evaluacio´ n ulticriterio en la ordenacio’ n delterritorio. Editorial RA-MA: Madrid, Espana: 310p.

Bartelli, L. J, 1966. Soil surveys and land use planning: Soil Science Society of America and American Society of Agronomy, Madison, *Wis*: 45-67.

Beek, K. J., K. de Bie and P. Driessen, 2000. Land information and land evaluation for landuse planning and sustainable land management: International Institute for Aerospace Survey and Earth Sciences (ITC). Enschede, The Netherlands: 19 p.

Berkes F., Folke C. and Gadgil M. 1995. Traditional ecological knowledge, biodiversity, resilience and sustainability. In: Perrings C.S., Maler K.G., Folke C., Holing C.S. and Jansson B.O. (eds), Biodiversity Conservation: Problems and Policies. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 281–300.

Betke, D., 1994. "Top down" meets "bottom up": zur Institutionalisierung der Landnutzungsplanung in Projekten der technischen Zusammenarbeit in Asien. In: Preuss and Roos (Eds.): Ländliche Entwicklung und regionales Ressourcenmanagement: Konzepte, Instrumente, Erfahrungen, Materialien 32, Justus-Liebig Universität Giessen, pp. 131-143

Bibby, J. S., H. A. Douglas, A. J. Thomasson and I. S. Robertson, 1991. Land capability classification for agriculture: Development of soil survey interpretations-Soil survey horizons. Macaulay Land Use Research Institute, Aberdeen. Klingebiel, *Vol. 32*: 53-66.

Binnie, 1988. Water Supply for Kathmandu Valley from outside the valley. Report prepared for Nepal Water Supply and Sewerage Co-operation, August, 1988. Kathmandu

Böhme, M., 1986. Die Erarbeitung technologischer Lösungen ausgewählter Anbauverfahren für die Gemüseproduktion in Gewächshäusern und deren Bewertung, Habilitation, Humboldt-Universität zu Berlin.

Boulaine, J., 1989. Histoire des pedologues et de la science des sols: Institut National de la Recherche Agronomique, Paris: 15.37.

Bouma, J., 1997. The land use systems approach to planning sustainable land management at several scales: ITC Journal, *Vol. 3/4*: 237-242. 211

Bouma, J., 1999. Land evaluation for landscape units: Sumner, M.E., CRC Press, Boca Raton, FL, (eds.): *E393-E412.*

Budhathoki, K., 2002. Vegetable Sustain Farmers, Lumle Regional Agricultural Research Centre, Unpublished documents, Pokhara Nepal.

Bydekerke L., E. Van Ranst, L. Vanmechelen and R. Groenemans, 1998. Land suitability assessment for cherimoya in southern Ecuador using expert knowledge and GIS, ELSEVIER, Agriculture, Ecosystems and Environment *69* (*1998*) 89±98

Carson Brian, 1992. The Land, the farmer and the future, A soil fertility management strategy for Nepal. ICIMOD occasional paper *No.* 21, Kathmandu, Nepal

Carver, S. J., 1991. Integrating multi-criteria evaluation with geographical information systems: International Journal of Geographical Information Systems, *Vol. 5 (3*): 321-339.

CBS, 2002. National Population Census 2001: Summary Sheet, Central Bureau of Statistics, National Planning Commission Secretariat, HMG of Nepal, Kathmandu, Nepal.

CBS, 2003. Population Monograph-2003. Central Bureau of Statistics, Kathmandu

CBS, 2005. A Report of Water Survey of Kathmandu - 2005. Kathmandu: NPC/CBS

CBS, 2005. Poverty Trends in Nepal (1995-96 and 2003-04). Kathmandu: Central Bureau of Statistics, NPC 2005

CBS, 2006. Monograph, Agriculture Census Nepal 2001/02, Central Bureau of Statistics, National Planning Commission Secretariate, Kathmandu, Nepal 2006

CBS, WFP and World Bank, 2006. Small Area Estimation of Poverty, Caloric intake and Malnutrition in Nepal, Central Bureau of Statistics and World Food Program of UN and world bank. PP46

Ceballos Silva, A and J. Lopez-Blanco, 2003. Delineation of suitable areas for crops using a multi- criteria evaluation approach and land use/cover mapping: a case study in Central Mexico: Agricultural Systems, *Vol. 77(2):* 117-136.

Chambers, R., 1994. The Origins and Practice of Participatory Rural Appraisal. World Development, Vol. *22*, *No. 7,* Elsevier Science Ltd., pp. 953-969

Chuong, M, 2007. Multi-criteria Land Suitability evaluation for selected fruit crops in Hilly Region of Central Vietnam. PhD dissertation submitted to Humboldt University of Berlin, Germany.

Chuong, V.H., Böhme M.H. and La Rosa, M. 2006. Social-economical Database Implementation into GIS to Analysis Land Suitability for Citrus Fruit Production; A Case Study in the Thua Thien Hue Province, central Vietnam. Tropentag, Bonn, Germany.

Cools N., E. De Pauwb, J. Deckers, 2003. Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: a case study in northwestern Syria. Agriculture, Ecosystems and Environment *95* (2003) 327–342

Davidson, D. A., 1992. The evaluation of land resources, Stirling university published in USA with John Wiley, NewYork.

de La Rosa, D., 2000. MicroLEIS 2000: Conceptual Framework: Instituto de Recursos Naturalesy Agrobiologia, CSIC, Avda. Reina Mercedes 10, 41010 Sevilla, Spain: *267* pp. 212

Dent, D and A. Yong, 1981. Soil survey and land evaluation: Allen & Unwin, London.

Di Gregorio, A and L. J. M. Jansen, 1998. A new concept for a land cover classification system: The Land, *Vol. 2*: 55-65.

DoAD (Department of Agricultural Development) 1992. Food Balance Sheet of Nepal, 1991/92. Agricultural Marketing Development Division, Harihar Bhawan, Lalitpur, Nepal

Dobermez, J.F., 1970. La Nepal Ecologic et biogeographie, Grenobel.

Dokuchaev V.V., 1883. Russian Chernozems (Russkii Chernozems). Israel Prog. Sci. Trans., Jerusalem, 1967. Transl. from Russian by N. Kaner. Available form U.S. Dept. of Commerce, Springfield, VA.

Eastman, J. R. 1997. IDRISI for Windows, version 2.0 (Tutorial Exercises): Graduate Schoolof Geography-Clark University, Worcester, MA.

ESRI, 1994. Cell-based modelling with GRID: ArcInfo Manual, *Version 7.0,* Environmental Systems Research Institute, Redlands, CA.

ESRI, 2001. ArcInfo Manual, Version 7.0, Cell-based modeling with GRID: Environmental Systems Research Institute, Redlands, CA

FAO and UNDP, 2003. Nepal : Agricultural Policy and Strategies For Poverty Alleviation and Food Security, Main Report, Kathmandu Nepal, June 2003.

FAO, 1976. A framework for land evaluation: *Soils Bulletin 32,* Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 1983. Guidelines: Land evaluation for rainfed agriculture: *Soils Bulletin 52,* Food and Agriculture Organization of the United Nations, Rome, Italy: 233 p.

FAO, 1984. Land evaluation for forestry, *forestry paper 48*: Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 1985. Guidelines: land evaluation for irrigated agriculture: *Soils Bulletin 55,* Food and Agriculture Organization of the United Nations, Rome, Italy: 219 p.

FAO, 1986. Land evaluation for development: Food and Agriculture Organization of theUnited Nations, Rome, Italy: *4-59* (74p).

FAO, 1988. FAO-UNESCO Soil Map of the World: Revised Legend. *FAO World Soil Resources Reports No. 60,* Rome: 119pp.

FAO, 1990. Guidelines for soil profile description: FAO, Rome, Italy: 66p.

FAO, 1991. Guidelines: land evaluation for extensive grazing: *Soils Bulletin 58,* Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 1993. An international framework for evaluating sustainable land management (FESLM): Rome, Italy.

FAO, 1993. Guideline for land use planning: *FAO development series 1, Vol.8* (96): Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 1994. Agricultural policy analysis for transition to a market-oriented economy in Vietnam, *FAO Paper No. 123.* Rome: 12-16.

FAO, 1995. Planning for sustainable use of land resources: Towards a new approach: *Land and Water Bulletin 2,* Rome, Italy: 53 p.

FAO, 1995. Programme for the World census of agriculture 2000: *FAO Statistical Development Series No.5*, FAO, Rome, Italy.

FAO, 1995. The Future of our land: Facing the challenges. FAO, Rome, Italy: 23-24.

FAO, 1996. Agro-ecological zoning, guidelines: FAO *Soils Bulletin 73*. FAO, Rome.

FAO, 1997. Africover land cover classification: FAO, Rome.

FAO, 1998. Terminology for Integrated Resources Planning and Management: available at: http://intranet.fao.org/offsiteframe.jsp?uu=http://www.fao.org/ag/agl/aglhomep.stm,

FAO, 2000. Farming System and Alleviating Poverty. New York, USA.

FAO, 2004. Statistical Database. New York, USA.

Frere, M., and G. Popov. 1979. Agrometeorological crop monitoring and forecasting. FAO, Plant production and protection Paper 17:64 pp.

Fresco, L. O., Huizing, H., Keulen, H. v., Luning, H. A., & Schipper, R. A. 1994. Land Evaluation and Farming Systems Analysis for Land Use Planning. FAO Working Document.

Gautam, I.P., K.P. Upadhyay, J.N. Choudhary and B. Khatri, 2004. Study on Inter Cropping Vegetables in Maize Based Cropping System in Tar Area of Western Nepal. Proceedings of IV National Conference on Science and Technology, RONAST 110-114pp

George, H, 2001. An overview of land evaluation and land use planning at FAO: Land and Plant Nutrition Management Service, AGLL, FAO, Rome, Italy: 3.

Ghafari, A., H. F.Cook, and H. C. Lee, 2000. Integrating climate, soil and crop information: a land suitability study using GIS.: 4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs.

Grahm, G.R. 1948. Determination of soil organic matter by means of photoelectric calorimeter, soil science *65*:181-183.

Gregorich , E. G., M. R. Carter., D. A. Angers., C. M. Monreal., B. H. Ellert, 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Can. J. Soil Sci. *74:* 367-386.

Gruhn P., Francesco Goletti and Montague Udelman, 1995. Fertilizer, Plant nutritient Management and sustainable agriculture: Usage, problems and challenges. Proceedings of the IFPRI/FAO workshop on plant nutrient management, food security and sustainable agriculture, Italy. 1995

Guillet, D. W., L. Furbee, and J. H. B. R. Sandor, 1996. The Lari soils project in Peru-a methodology for combining cognitive and behavioral research. In: Warren, D., Slikkerveer, J.L., Brokensha, D. (Eds.): The Cultural Dimension of Development: Indigenous Knowledge Systems, Intermediate Technology Publications, London: 77-81.

Guo, L. S., and Y. S. He, 1998. Integrated multi-criteria decision model: A case study for the allocation of facilities in Chinese Agriculture: J. Agric. Engng Res. (1999), Silsoe Research Institute (*Article No. jaer.1998.0393,* available online at http://www.idealibrary.com), *Vol. 73*: 87-94.

Ha, V. H and T. B. Phạm, 2003. Ket qua danh gia tong hop dieu kien tu nhien bang Phuong phap canh quan cho phat trien nong lam nghiep o huyen Hai Lang, tinh Quang Tri (General evaluation Result of natural conditions by landscape method for agro –

forestry development in hai lang district, Quang Tri province): Science Journal of Hue University, Hue, Vol. *20(9)*: 67-73.

Hagen, T. 1998. Nepal - the Kingdom in the Himalaya (4th edn). Himal Books, Lalitpur, Nepal

Halcrow Fox and Associatges, 1991. Kathmandu Valley Urban Development Plans and Programme. Department of Housing and Urban Development, Kathmandu

Heit, M and A. Shortreid (Eds), 1991. GIS applications in natural resource: Colorado, GIS World.

Hemmati, M., 2002. Multi-stakeholder processes for governance and sustainability: beyond deadlock and conflict. London, Earthscan.

HMG/IUCN, 1995. Regulating Growth: Kathmandu Valley, National Planning Commission, HMG collaboration with IUCN, Kathmandu, Nepal.

HMGN/MOF, 2001. Economic Survey, Fiscal Year 2000/2001, Ministry of Finance, Kathmandu, Nepal.

Ho, K and C. V Huynh, 2004. Danh gia tinh hinh quan ly va su dung dat go doi huyen Huong Tra, tinh Thua Thien Hue (Investigation and assessment to land use management in the hilly area of Huong Tra district, Thua Thien Hue province): Science Journal of Hue University, Hue, *Vol. 21*, 5-13.

Hossain, M. S. S. R. Chowdhury, N. Gopal Das and M. M. Rahaman, 2007. Multi-criteria evaluation approach to GIS-based land-suitability classification for tilapia farming in Bangladesh, Journal of the European Aquaculture Society Springer Science+Business Media B.V. 2007

Huizing, H. A., Farshad and C. Debie, 1995. Land evaluation (ITC lecture notes): ITC, Enschede, The Netherlands.

Hussein Harahsheh, 1994. Agricultural Applications of Remote Sensing and Geographic Information System in Land-use and Land Suitability Mapping, Royal Jordanian Geographic Centre, Amman-Jordan 1994

ICIMOD, 1999. Mountains 2000 and Beyond. ICIMOD, Kathmandu.

ICIMOD, CBS/HMGN and SNV, 2003. Districts of Nepal Indicators of Development Update 2003, ICIMOD, Kathmandu, Nepal.

IDWG/LUP, 1994. Glossary of land use terms, Working Paper, Draft. Interdepartmental Working Group on Land Use Planning Subgroup *1: Methodology*. FAO, Rome.

IUCN, 1991. Sources of Industrial Pollution in Nepal – A National Survey. Kathmandu: National Conservation Implementation Programme and National Planning Commission, in collaboration with IUCN

Jamal, B. N., 2003. Land evaluation for land use planning with especial attention to sustainable fodder production in the Rouzeh Chai catchment of Orumiyeh area - Iran., MSc thesis, ITC, Netherlands: *17* (145p).

Kalogiroua S., 2002. Expert systems and GIS: an application of land suitability evaluation Computers, Environment and Urban Systems *26* (2002) 89–112

Karki, T.K., 1991. Establishing and Expanding the Private Sector Land Development Industry in Greater Kathmandu, Nepal (Unpublished M. Sc. Thesis), Asian Institute of Technology, Bangkok.

Kavetskiy, S., M. Kraynyuk., G. Hofman., M. Boehme., O. V. Cleemput, 2003. Soil quality and fertilization. Joint European Project, Tempus Tacis, *Kyiv: 5-9* (243pp).

KFVMDB, 2007. Early report of pricing and arrival of vegetable 2007. Kalimati Fruits and Vegetable Market Development Board, Kathmandu.

Khan, M. H., 2000. Rural Poverty in Developing Countries: Issues and Policies. Washington, DC, International Monetary Fund: *32.*

Kumar, R., 1996. Research Methodology, a Step-by-Step Guide for Beginner. Longman, Melbourne, Australia, pp. 74.

Kundiri, A. M., M. G. Jarvis and P. Bullock, 1997. Traditional soil and land appraisal on fadama lands in northeast Nigeria: Soil Use Manage, *Vol. 13:* 205-208.

KVTDC, 2002. Kathmandu Upatyakako Dirghakalin Bikash Abadharana, Kathmandu Valley Town Development Committee, Nepal.

KVWMP, 1994. Kathmandu Valley Watershed Management Project, Project Report. 1994.

Larson, W. E and J. F. Pierce, 1991. Conservation and enhancement of soil quality. In: Evaluation for sustainable land management in the developing world. International Board Soil Resarch and Management, Bangkok, Thailand: 115-203.

LRMP, 1986. Land Utilization Report. Land Resource Mapping Project, HMG, Kathmandu

Malczewski, J. 2004. GIS-based land-use suitability analysis: a critical overview: Progress in Planning, 2003 Elsevier Ltd., *Vol. 62*: 3-65.

Malczewski, J. 2004. GIS-based land-use suitability analysis: a critical overview: Progress in Planning, 2003 Elsevier Ltd., *Vol. 62:* 3-65.

Marsh Sally P. and T. Gordon MacAulay , 2002. Land reform and the development of commercial agriculture in Vietnam: policy and issues. Agribusiness Review - *Vol. 10 Paper 1* 2002

Mau Crimmins, T., J. E. de-Steiguer and D. Dennis, 2003. AHP as a means for improving public participation: a pre-post experiment with university students: Forest Policy and Economics, Elsevier *B.V: 15*

Midmore, D. J., Hans G. P. Jansen and Robert G. Dumsday, 1996. Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysia Agriculture, Ecosystems & Environment, Science Direct *60 : 1*, November 1996, 29-46

Ministry of Agriculture, food and fisheries, 2004. AGFocus: A Guide to Agricultural Land Use Inventory, Australia Revised October 2004.

MoA, 2005. Annual Progress Report, Ministry of Agriculture, Kathmandu, Nepal.

Moldovanyi, A, 2003. GIS and multi-criteria decision making to determine marketability of pay pond businesses in West Virginia., Division of Forestry, West Virginia University.

Mongkolsawat, C. P., Thirangoon, and P. Kuptawutinan, 2002. A physical evaluation of land suitability for rice: A methodological study using GIS.: Computer Centre, Khon Kaen University, Thailand (online at http://www.gisdevelopment.net).

MoPE, 2003. Nepal Population and Environment Facts and Figures, Ministry of Population and Environment, Kathmandu, Nepal.

NARC, 1988. Annual Report. Nepal Agriculture Resarch Council, Vegetable Development Division (VDD), Khumaltar, Kathmandu. Pp 148

NARC, 2006. Vegetable Research Highlights, NARC Annual Report, Nepal agriculture Research Centre, Kathmandu (www.narc.gov.np)

Nayava, J. L., 1981. Arial Rainfall in the Kathmandu valley. Mausam, 32: 4 343-348

Nayava, J. L., 2005. "The estimation of evapotranspiration by climate models for Western Nepal", SOHAM-Nepal, Journal of Hydrology and Meteorology, *Vol. 2, No. 1*, pp. 16 – 23.

NBS, 2002. Nepal Biodiversity Strategy, His Majesty's Government, Nepal, Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

Nepal Rastra Bank, 1999. Household Budget Survey: Urban Nepal, (mid July 1995-Mid July 1996), Nepal Rastra Bank, Kathmandu, Nepal.

Nguyen, N. C. 2004. Ket qua buoc dau nghien cuu giam ngheo theo phuong phap cung tham gia o xa Binh Thanh, huyen Huong Tra, tinh Thua Thien Hue (Some primary results of participatory poverty assessment of binh thanh commune,huong tra district, thua thien hue province): Science Journal of Hue University, Hue, *Vol. 23* (2004): 88-94.

Nguyen, V. N. 1996. Dac diem dat dai va danh gia kha nang su dung dat trong san xuat nong nghiep cua vung dong bang song Cuu Long (Soil characteristics and agricultural land\useable assessment of Cuu Long river delta region: PhD dissertation, Hanoi University of Agriculture, Hanoi, Vietnam.

NIDI, 2006. District Profile, 2006. Kathmandu: Nepal Information Development Institute sourced from Department of Postal Services

Norton, J. B., R. Roman, and J. A. Sandor, 1998. Observation and experience linking science and indigenous knowledge at Zuni, New Mexico: J. Arid Environ (Eds), *Vol. 39:* 331-340.

NPC (National Planning Commission), 1992. Eighth Five Year Plan, 1992-93 to 1996-97 (In Nepali). NPC, Kathmandu, Nepal. pp: 144-146.

NPC, 2003. The Tenth Plan (Poverty Reduction Strategy Paper) summary 2002-2007. National Planning Commission, Kathmandu, Nepal. July 2003.

NRB (Nepal Rastra Bank), 1989. Multipurpose household budget survey: A study on income distribution, employment, and consumption patterns in Nepal. NRB, Kathmandu, Nepal.

NRB, 1980. Agricultural credit review survey, Nepal. Nepal Rastra Bank, Kathmandu, Nepal.

NWSC, 2004. Annual Report, 2004. Nepal Water Supply Corporation, Kathmandu

Obi Reddy, B. P., A. K. Maji, C. Srinivas, K. H. Kamble and M. Velayutham, 2002. GIS\ based basin morphometric information system for terrain and resources analysis.: First National Conference on Agro-Informatics: 37-42.

Oli P. P. 2001. Spatial Date for Land Use Planning in Nepal, International Conference on Spatial Information for Sustainable Development, Nairobi, Kenya

Omakupt, M and H. Huizing, 1992. Land evaluation and land use planning. In: The Workshop on GIS and RS for Natural Resources Management by ILWIS: 23-29.

PACMAR (Pacific Management Resources Inc.) and EC (East Consult (P) Ltd.). 1991. Master plan for horticulture development. Various volumes. Project Report Submitted to His Majesty's Government of Nepal and Asian Development Bank. pp: 43.

Papendick, R. I; P. I. Parr and L. van Schilfgaarde, 1995. Soil quality: New perspective for sustainable agriculture. In: Proc. International Soil Conservation Organization, New Delhi, India, 1995.

Permadi, 1992, inharited from Chuong, M, 2007. Multi-criteria Land Suitability evaluation for selected fruit crops in Hilly Region of Central Vietnam. PhD dissertation submitted to Humboldt University of Berlin, Germany.

Pettapiece W.W., 1995. Land Suitability Rating System for Agricultural Crops. A technical report prepared by Agronomic Interpretations Working Group, Agriculture and Agri Food Canada. 1995

Piper, C.S. 1942. Soil plant analysis. How publishers. Bombay, India.

Poudyal, S. 1983. Planned Development in Nepal: A Study, Educational Enterprises (Pvt.) Ltd., Kathmandu, Nepal.

Pradhan P and R. Perara, 2005. Urban growth and its impact on the livelihoods of Kathmandu Valley, Nepal, *UMP-Asia Occasional Paper No. 63*. Urban Management Program for Asia and the Pacific, Feb 2005

Prakash, T. N. 2003. Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach, MSc thesis, ITC, Netherlands: 6-13.

Ranjit R., B.Shakya, 2005. A High Flow Turning Into Catastrophic Floods In Kathmandu Valley, Unpublished documents, Tribhuvan University Kathmandu, Nepal

Rao, M., Sastry, S.V.C., Yadav, P.P., Kharod, K., Pathan, S.K., Dhinwa, P.S., Majumdar, K.L., 1991. A Weighted Index Model for Urban Suitability Assessment and GIS Approach (Report No. SAC/RSA/NRIS-URIS/TN-03/Feb) Space Applications Centre, Ahmedabad, India.

Rossiter, D. G 1996. A theoretical framework for land evaluation (with Discussion): Geoderma, *72* (1996): 165-202.

Rossiter, D. G. 1994. Lecture Notes: "Land Evaluation", Part 1: Basic concepts & procedures of land evaluation. Department of Soil, Crop, & Atmospheric Sciences, College of Agriculture & Life Sciences, Cornell University: 14-15 (*58*).

Rossiter, D. G. 1995. Economic land evaluation: why and how, Soil Use & Management Dept of Soil, Crop & Atmospheric Sciences, Cornell University: *2. 11*: 32-140,

Saaty, L.and Luis G. Vargas. 1988. Decision Making in Economic, Political, Social, and Technological Environment with the Analytic Hierarchy Process. RWS Publications, Pittsburgh, USA, 1-13 pp.

Saaty, T. L 1977. A scaling method for priorities in hierarchical structure: Journal of Mathematical Psychology *15.3*: 34-39.

Saaty, T. L 2000. Fundamentals of decision making and priority theory with the analytic hierarchy process: RWS Publications, Pittsburgh., *Vol. 6*: 21-28

Saaty, T. L and L. G. Vargas, Eds 2001. Models, methods, concepts & applications of analytical hierarchy process.: International Series in Operations Research and Management sciences. Boston/Dodrecht/London, Kluwer Academic Publishers.

Saaty, T. L. 1980. The analytic hierarchy process: McGraw Hill International., New York.

Sachs, I. 1992. Transition Strategies for the 21st Century. Nature and Resources, *28*:4-17.

Saptana, Saktyanu K.D., et. al. 2004. Integrasi Kelembagaan Forum KASS dan Program Agropolitan dalam rangka Pengembangan Agribisnis Sayuran Sumatera Utara. Analisis Kebijakan Pertanian. Pusat Penelitian dan Pengembangan Sosial Ekonomi Pertanian. Bogor, Indonesia, pp. 268-270.

Sharifi, M. A and M. V. Herweijnen, 2003. Spatial decision support systems: Enschede, ITC.

Sharifi, M. A., K. Shamsudin and L. Boerboom, 2004. Evaluating rail network options using multiple criteria decision analysis (MCDA): case study Klang Valley, Malaysia: 24-35.

Sharma, P. 1990. Perspective on Urbanization in Nepal, Papers of the East-West Population Institute, Honolulu.

Shi, S. 2002. Research on the Urban Spatial Structure Guided by the Urban Green Space System. Physical Geography., Central China Normal University Wuhan: *112*

Shrestha Sundar S. 2003. GIS and Agricultural Economics, GIS Resource Document *03-54 (GIS_RD_03-54)* March 2003

Shrestha, B. and Pradhan, S. 2000. Kathmandu Valley GIS database, Bridging the data gap. ICIMOD and UNEP, Kathmandu

Shrestha, D.P., 2000. Aspects of erosion and sedimentation in the Nepalese Himalaya, Highland low land relations. ITC *Dissertation no 77* (10-227p)

Siderius, W., (ed) 1986. Land evaluation for land-use planning and conservation in sloping areas: *ILRI Publication 40,* Wageningen: International Institute for Land Reclamation and Improvement (ILRI): *S605.I61p no. 40* Mann.

SMEC, 1992. Greater Kathmandu Water Supply Project. Cemat, Scott and Murphy, Kathmandu

SOTER database, 2004. Global and National Soils and Terrain Digital Databases (SOTER),

Stainton, J, D. A. 1972. Forest of Nepal, John Murry, London

Store, R., Kangas, J., 2001. Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. Landscape and Urban Planning *55 (2),* 79–93.

Subedi A. G. Holt and C. Garforth, 2002. Review of Land Management Policy in Nepal, DFID NRSP R7958 Linking Field Level Findings with Policy Making in Nepal working paper 1. DFID, Feb 2002

Suman S. 2005. Estimation of Net Solar radiation & Upper evaporative water loss i.e. evapotranspiration (ET) using climatic models by Modified Penman-Monteith method in Kathmandu valley. M. Sc. Dissertation submitted to DMH, TU Kathmandu.

Thapa Rajesh Bahadur and Yuji Murayama, 2006. Land Use Change Analysis Using Remote Sensing and GIS: A Case Study of Kathmandu Metropolitan, Nepal, *CSIS DAYS C4*, pp 22, 2006

Tomlinson, R. F, 1987. Current and potential uses of geographical information systems: The North American experience: International Journal of Geographical Information Systems, *Vol. 1:* 203-218.

Tuladhar Arbind Man, Krishna Raj BC and Nama Raj Budhathoki, 2004. Towards Strategic Planning For Building Land Information System (Lis) In Nepal, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede THE NETHERLANDS

UNDP, 2004. Factsheets of Nepal, http://hdr.undp.org/ statistics/data/ cty/cty_f_ NPL.html, Dec 8, 2004

UNDP, 2006. Human Development Report, Highlights, United Nations Development Program, 2006. (http://hdrstats.undp.org/countries/ countryfact_sheets /cty_fs_ NPL.html)

Upreti B. R. and Yamuna Ghale Upreti, 2002. Factors leading to agro-biodiversity loss in developing countries: the case of Nepal Biodiversity and Conservation, Kluwer Academic Publishers *11:* 1607–1621, 2002.

USAID, 1988. The transition to sustainable agriculture: an agenda for A.I.D: Committee for Agr. Sust.for Developing Countries, Washington D.C.

Van der Merwe and Hendrik Johannes, 1997. GIS-aided land evaluation and decision-making for regulating urban expansion: A South African case study GeoJournal *43*: 135–151

Van Diepen, C. A., H. van Keulen, J. Wolf, and J. A. A. Beout, 1991. Land evaluation: from intuition to quantification. In: B.A. Stewart (Editor): Advances in Soil Science, Springer, New York, *Vol. 15*: 139-204.

Venkataratnam, L. 2002. Remote sensing and GIS in agricultural resources management. In: First National Conference on Agro-Informatics: INSAIT.

Verheye., W. H., 1996. Advanced course on land evaluation and land use planning. Sierra Leone, 4-16 July 1996. FAO & Government of Sierra Leone Land Use Committee. FAO, Rome.

Vink, A. P. A, 1975. Land use in advancing agriculture: Springer Verlag. Germany: 122p.

Vo Quang Minh1, Le Quang Tri1, Yamada, 2003. Delineation and incorporation of socio-infrastructure database into GIS for land use planning: A case study of Tan Phu Thanh village, ChauThanh District, Cantho Province. Land Use Analysis, Map Asia 2003

Vo, Q. M., T. Q. Le and Yamada, 2003. Delineation and incorporation of socio infrastructure database into GIS for land use planning in Tan Phu Thanh village, ChauThanh District, Cantho Province.: Land use analysis, Map Asia Conference 2003: 14-16.

Voogd, H, 1983. Multicriteria Evaluation for Urban and Regional Planning: Pion, London: 74p.

Wandahwa P. and E. van Ranst, 1996. Qualitative land suitability assessment for pyrethrum cultivation in west Kenya based upon computer-captured expert knowledge and GIS. Agriculture, Ecosystem and Environment *56* (1996) 187-202

WCED, 1987. Our Common Future: Oxford University Press, UK: 400p.

World Bank, 1992. World development Report: Development and environment. Washington, D.C.

Yaalon, D. H and S. Berkowicz, (ed), 1997. History of soil science: international perspectives.: Catena Verlag GMBH, Reiskirchen.

Zinck, J. A., 1995. Soil survey: perspectives and strategies for the 21st century: FAO/ITC, Rome.

Zurayk, R., F. El Awar, S. Hamadeh, S. Talhouk, C. Sayegh, A. Chelab, and K. Al-Shab 2001 Using indigenous knowledge in land use investigations: a participatory study in a semi-arid mountainous region of Lebanon.: Agric. Ecosyst. Environ, *Vol. 86:* 247-262.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

APPENDIX

Appendix Table: 1 Trends of urban and agricultural land use in the valley

Year	**1984**	**1991**	**1994**	**2000**	**2010**	**2020**
Urban area (% of total valley area)	4.8	11.0	13.1	18.0	26.0	34.3
Agricultural area (% of total valley area)	64.0	56.0	49.6	42.2	28.3	14.5

Source : Pradhan and Parera ,2005

Appendix Table: 2 Consumption figures in Kathmandu valley

Category	1996 Consumption (kg/capita/year)	Total Demand in 2000/01 (kg) in '000	Projected Demand in 2015/16 (kg) in '000
Vegetable	66.2	10,664	174,755
Fruit	11.3	18,814	43,587
Spices	3.0	3,912	7,368

Appendix Table: 3 Soil texture type of valley districts identified by national sample agricultural census, 2001/02

		Districts		
SN	Soil type	Kathmandu	Lalitpur	Bhaktapur
	Sand (Balaute)	4366.3	3039.0	1033.8
	Loam (Domat)	1967.0	1062.4	631.2
	Silt (Pango)	1784.7	1443.1	538.4
	Clay (Chimtyalo)	3909.7	3237.5	1217.6
	Clay Loam (Chimtylo Domat)	240.0	93.7	109.6
	Area (ha)	13285.4	9958.6	6000.1

Appendix Table: 4 Revenue Cost Ratio for the vegetable cultivation in Kathmandu Valley

Particulars	Average
LAND AREA	1 Ropani*
A. INCOME	**31700**
B. VARIABLE COST	**25,329,721**
1. Seed	**650**
2. Fertilizer	**4650**
2.1. Inorganic	900
2.9. Organic	380
2.10. Other (Lime)	70
3. Pesticide	**740**
3.1. Insecticide	150
3.4. Fungicide	50
4. Labor	**6920**
4.2. Land preparation	
4.4. Planting	
4.5. Mulching / Staking	
4.7. Irrigation / Fertilizing	
4.11. Harvesting	
4.16. Value addition	
4.17. Transporting	300
C. GENERAL COST	**7990**
5. Tax/ Rent	3000
7. Interest	50
10. Social Cost	
13. Maintenance	500
14. Depreciation	300
D. FIX COST	**3200**
15. Staking/Mulch	700
19. Transportation	200

	24150
C. Net Benefit	7550
D. R/C Ratio	1.3126294

* 1 Ropani of land = 0.025ha.

Appendix Table: 5 Nepal's human development index (HDI) 2005

HDI value		Adult literacy rate (% ages 15 and older)	Combined primary, secondary and tertiary gross enrolment ratio (%)	GDP per capita (PPP US$)
1. Iceland (0.968)	1. Japan (82.3)	1. Georgia (100.0)	1. Australia (113.0)	1. Luxembourg (60,228)
142. Nepal (0.534)	131. Nepal (62.6)	126. Nepal (48.6)	136. Nepal (58.1)	148. Nepal (1,550)
177. Sierra Leone (0.336)	177. Zambia (40.5)	139. Burkina Faso (23.6)	172. Niger (22.7)	174. Malawi (667)

Source: UNDP, 2006

Appendix Table: 6 Major indices level of development

Index	**Kathmandu**	**Lalitpur**	**Bhaktapur**
Overall composite index	1	3 (5)	2 (4)
Poverty deprivation index	1 (9)	3 (21)	2 (12)
Scio-economic and infrastructural development index	1	3	2
Women's empowerment index	1 (2)	2 (9)	3 (19)

Appendix Table: 7 Health and primary sector development

Indicator	**Kathmandu**	**Lalitpur**	**Bhaktapur**
Health Development Index	**1**	**3**	**2**
Contraceptive prevalence rate %	77.42	77.2	73.14
Drinking water coverage %	90.3	84.77	82.45
Toilet facilities %	93.2	81.68	91.44
Primary Sector Development Index	**3 (72)**	**1 (43)**	**2 (47)**
Agricultural credit %	3.48	9.94	2.9
Farm size %	0.24	0.29	0.22
Livestock per farm household %	3.64	4.52	3.37
Irrigated area in %	41.43	57.4	88.88

Source: ICIMOD et.al., 2003

Appendix Table: 8 Infrastructural development in the Kathmandu valley

Indicator	Kathmandu	Lalitpur	Bhaktapur
Infrastructural development index	1	3	2
Road density 100 sq. km	203.54	87.79	148.74
Cooperatives density (%)	27.69	23.39	25.37
Health institutions density (%)	3.48	3.77	4.25
Forest user households (%)	6.37	15.33	17.37
Per capita budget expenditure (NRs.)	20,537	1,500	1,278
Per capita development budget expenditure (NRs.)	16,532	4,238	4,871
Overall literacy rate (%)	77.21	70.92	70.57
Ratio of non-agricultural and agricultural occupation (%)	3.69	1.78	1.41

Source: ICIMOD et.al., 2003

Appendix Table: 9 Population distribution form 1971 to 2001

Year / Districts	1971	1981	1991	2001	Area Sq. km
Kathmandu	353,756	422,237	675,341	1,081,845	395
Lalitpur	154,998	184,341	257,086	337,785	385
Bhaktapur	110,157	159,767	172,952	225,461	119
Kathmandu Valley	**618,911**	**766,345**	**1,105,379**	**1,645,091**	**899**

Source: ICIMODet.al., 2003

Appendix Table: 10 Land characteristics of each LMU in Kathmandu valley

		Altitude	Slope	Soil depth	Area
LU_ID	SOIL_TYPE	ALT_CLASS	SL_CLASS	D_CLASS	(ha)
1	Dystrochrept Anthropic	AL2	SL4	D5	13.066
2	Ustochrept Paralithic	AL2	SL4	D4	3541.752
3	Dystrochrept Aquic	AL2	SL2	D1	572.377
4	Ustifluvent Aquic Anthropic	AL2	SL3	D4	338.309
5	Dystrochrept Anthropic	AL2	SL5	D4	154.321
6	Dystrochrept Anthropic	AL2	SL4	D4	552.276
7	Dystrochrept Anthropic	AL2	SL4	D4	303.668
8	Dystrochrept Anthropic	AL1	SL4	D5	29.352
9	Rhodustalf Scalpic	AL1	SL2	D3	221.160
10	Fluvaquent Aeric	AL1	SL1	D1	2834.244
11	Rhodustalf Anthropic Udic	AL1	SL2	D2	144.105
12	Fluvaquent Aeric	AL1	SL1	D3	32.505
13	Rhodustalf Scalpic	AL1	SL2	D2	178.368
14	Rhodustalf Scalpic	AL1	SL2	D3	109.874
15	Dystrochrept Anthropic	AL1	SL5	D3	7.610
16	Rhodustalf Anthropic Udic	AL1	SL2	D2	193.556
17	Rhodustalf Anthropic Udic	AL1	SL2	D2	71.698
18	Rhodustalf Anthropic Udic	AL1	SL2	D3	43.127
19	Rhodustalf Scalpic	AL1	SL2	D2	134.258
20	Rhodustalf Scalpic	AL1	SL2	D3	81.969
21	Dystrochrept Anthropic	AL2	SL5	D4	45.475
22	Rhodustalf Anthropic Udic	AL1	SL2	D2	118.553
23	Rhodustalf Scalpic	AL1	SL2	D2	12.482
24	Rhodustalf Scalpic	AL1	SL2	D2	642.409
25	Rhodustalf Anthropic Udic	AL1	SL2	D2	89.694
26	Rhodustalf Anthropic Udic	AL1	SL2	D2	41.648
27	Fluvaquent Aeric	AL2	SL1	D2	102.026
28	Rhodustalf Anthropic Udic	AL1	SL2	D1	128.712
29	Ustifluvent Aquic Anthropic	AL1	SL3	D5	75.650
30	Rhodustalf Anthropic Udic	AL1	SL2	D1	2.507
31	Rhodustalf Scalpic	AL1	SL2	D2	14.763
32	Ustifluvent Aquic Anthropic	AL1	SL3	D5	21.325
33	Rhodustalf Anthropic Udic	AL1	SL2	D2	38.823
34	Rhodustalf Anthropic Udic	AL1	SL2	D2	58.757
35	Ustochrept Aquic	AL1	SL1	D2	19.522
36	Rhodustalf Anthropic Udic	AL1	SL2	D1	38.642

37	Fluvaquent Aeric	AL1	SL1	D3	137.242
38	Ustochrept Aquic	AL1	SL2	D1	86.347
39	Dystrochrept Anthropic	AL1	SL4	D3	0.000
40	Fluvaquent Aeric	AL1	SL1	D2	179.569
41	Fluvaquent Aeric	AL1	SL1	D2	44.719
42	Rhodustalf Anthropic Udic	AL1	SL2	D2	136.646
43	Rhodustalf Scalpic	AL1	SL2	D3	84.606
44	Ustochrept Paralithic	AL2	SL4	D4	2424.038
45	Rhodustalf Scalpic	AL1	SL2	D2	35.400
46	Dystrochrept Anthropic	AL2	SL4	D5	23.053
47	Rhodustalf Anthropic Udic	AL1	SL2	D2	102.760
48	Rhodustalf Scalpic	AL1	SL2	D2	1531.503
49	Ustifluvent Aquic Anthropic	AL2	SL3	D4	858.522
50	Ustochrept Aquic	AL1	SL1	D1	522.041
51	Rhodustalf Anthropic Udic	AL1	SL2	D3	473.766
52	Ustochrept Aquic	AL1	SL1	D2	34.467
53	Ustochrept Aquic	AL1	SL2	D2	94.478
54	Rhodustalf Anthropic Udic	AL1	SL2	D1	12.798
55	Rhodustalf Scalpic	AL1	SL2	D2	735.649
56	Ustochrept Aquic	AL1	SL1	D2	55.872
57	Ustochrept Aquic	AL1	SL1	D1	58.905
58	Ustochrept Aquic	AL1	SL1	D2	6.978
59	Fluvaquent Aeric	AL1	SL1	D2	30.318
60	Rhodustalf Anthropic Udic	AL1	SL2	D1	92.442
61	Rhodustalf Anthropic Udic	AL1	SL2	D2	516.945
62	Fluvaquent Aeric	AL1	SL1	D1	107.207
63	Fluvaquent Aeric	AL1	SL1	D2	436.544
64	Dystrochrept Anthropic	AL1	SL4	D4	3.691
65	Fluvaquent Aeric	AL1	SL1	D2	113.046
66	Ustochrept Aquic	AL1	SL2	D2	78.675
67	Rhodustalf Anthropic Udic	AL1	SL2	D2	43.349
68	Rhodustalf Anthropic Udic	AL1	SL2	D2	293.839
69	Rhodustalf Anthropic Udic	AL1	SL2	D2	22.514
70	Ustochrept Aquic	AL1	SL2	D1	111.046
71	Rhodustalf Scalpic	AL1	SL2	D1	522.129
72	Ustifluvent Aquic Anthropic	AL1	SL3	D5	141.200
73	Fluvaquent Aeric	AL1	SL1	D2	85.247
74	Ustifluvent Aquic Anthropic	AL1	SL3	D4	68.607
75	Ustochrept Aquic	AL1	SL2	D1	34.423
76	Rhodustalf Scalpic	AL1	SL2	D1	914.398

77	Rhodustalf Scalpic	AL1	SL2	D2	228.956
78	Rhodustalf Anthropic Udic	AL1	SL2	D2	127.960
79	Rhodustalf Scalpic	AL1	SL2	D1	5.856
80	Dystrochrept Anthropic	AL2	SL4	D5	1.824
81	Dystrochrept Anthropic	AL1	SL4	D4	47.784
82	Fluvaquent Aeric	AL1	SL1	D2	148.047
83	Dystrochrept Anthropic	AL1	SL4	D3	551.126
84	Rhodustalf Scalpic	AL1	SL2	D1	62.004
85	Dystrochrept Anthropic	AL1	SL5	D4	82.213

Appendix Table: 11 Fertility rating of the individual LMU in the Kathmandu valley

LMU_ID	Soil Paremeters								AREA(ha)
	PH	OM	WHC	TOT_N	P2O5	K2O	T_FERT	T_CLASS	
1	VL	VL	M	L	M	M	L	T5	13.066
2	VL	VH	M	M	M	L	L	T5	3541.752
3	L	M	H	H	M	L	L	T3	572.377
4	L	VL	M	L	VL	L	VL	T1	338.309
5	VL	VL	L	L	M	M	L	T5	154.321
6	VL	L	M	L	VL	L	VL	T1	552.276
7	L	M	L	L	H	M	L	T3	303.668
8	M	M	M	M	L	L	L	T4	29.352
9	M	M	M	M	VL	L	VL	T5	221.160
10	M	M	M	M	H	M	M	T1	2834.244
11	M	M	M	M	H	H	M	T1	144.105
12	M	M	L	M	H	H	M	T4	32.505
13	M	H	M	M	H	M	M	T1	178.368
14	VL	VL	L	M	VL	M	VL	T1	109.874
15	VL	L	L	L	M	M	L	T5	7.610
16	M	M	M	M	H	M	M	T3	193.556
17	M	M	M	M	H	M	M	T1	71.698
18	L	H	H	H	H	M	M	T1	43.127
19	VL	M	L	M	H	M	M	T1	134.258
20	M	L	M	M	H	M	L	T4	81.969
21	M	M	M	M	H	M	M	T5	45.475
22	M	M	M	M	M	M	L	T3	118.553
23	M	M	M	M	M	M	M	T2	12.482
24	M	L	M	L	VL	M	VL	T1	642.409
25	L	H	M	M	H	M	L	T1	89.694
26	L	M	H	M	H	M	M	T4	41.648
27	M	M	M	M	M	M	M	T1	102.026
28	L	H	M	H	H	M	L	T2	128.712
29	M	H	H	M	H	M	M	T5	75.650
30	VL	M	M	M	H	M	M	T1	2.507
31	M	M	M	M	H	M	M	T3	14.763
32	VL	M	M	M	L	M	M	T3	21.325
33	L	H	M	M	H	M	L	T1	38.823
34	M	H	M	M	H	M	M	T1	58.757
35	VL	M	M	L	H	M	L	T2	19.522
36	M	M	M	M	H	M	M	T2	38.642
37	L	M	M	M	H	M	L	T3	137.242
38	VL	M	M	M	H	M	M	T2	86.347
39	VL	H	M	M	H	M	M	T1	0.000
40	M	M	L	M	VL	M	L	T1	179.569
41	M	H	M	M	H	M	M	T1	44.719
42	L	M	M	L	H	M	L	T1	136.646
43	VL	H	M	H	L	M	L	T1	84.606
44	M	H	M	M	H	M	M	T4	2424.038
45	VL	M	L	M	H	M	M	T4	35.400

46	M	M	L	M	H	M	M	T5	23.053
47	M	M	H	L	H	M	L	T1	102.760
48	M	M	H	M	M	M	M	T1	1531.503
49	L	M	H	M	H	M	M	T1	858.522
50	M	M	H	L	H	M	L	T2	522.041
51	M	M	M	M	H	M	M	T1	473.766
52	M	M	M	M	VL	M	VL	T2	34.467
53	L	M	M	M	H	M	M	T1	94.478
54	M	M	M	M	M	M	M	T2	12.798
55	L	M	M	M	H	M	M	T4	735.649
56	VL	M	M	L	M	M	L	T2	55.872
57	L	VL	L	L	H	M	L	T2	58.905
58	M	H	M	M	H	M	M	T2	6.978
59	VL	L	M	L	M	M	L	T1	30.318
60	M	M	M	M	H	M	M	T2	92.442
61	VL	M	L	M	H	M	M	T4	516.945
62	VL	L	L	L	M	M	L	T1	107.207
63	M	M	M	L	M	M	L	T1	436.544
64	M	M	L	M	L	M	L	T5	3.691
65	VL	L	M	M	H	M	M	T1	113.046
66	M	M	M	M	L	M	M	T4	78.675
67	VL	M	M	M	H	M	M	T2	43.349
68	M	M	M	M	H	M	M	T1	293.839
69	VL	M	M	M	M	M	M	T4	22.514
70	M	H	H	M	M	M	M	T4	111.046
71	VL	H	M	M	M	M	M	T2	522.129
72	VL	H	M	L	M	M	L	T5	141.200
73	M	M	H	M	H	M	M	T1	85.247
74	M	H	H	M	H	M	M	T1	68.607
75	M	H	M	M	H	M	M	T1	34.423
76	VL	M	M	M	L	M	M	T2	914.398
77	VL	H	M	M	H	M	M	T2	228.956
78	VL	H	M	M	M	M	M	T2	127.960
79	VL	M	H	M	H	M	M	T1	5.856
80	M	H	M	VH	M	M	M	T5	1.824
81	M	H	M	M	H	M	L	T4	47.784
82	M	L	H	M	H	M	M	T1	148.047
83	VL	M	H	M	L	M	L	T1	551.126
84	M	H	H	M	H	M	L	T1	62.004
85	VL	H	M	M	H	M	M	T5	82.213

H: High, M: Medium, L: Low and VL: Very Low

Appendix Table: 12 Current suitability ratings of diagnostic characteristics vegetable cultivation

Land units	Area	Suitability Status of Diagnostic Characters										Suitability
		t^o	r	hu	s	p	a	t	d	w	sl	
1	13.06	S1	S1	S1	S1	N	S2	N	S3	S1	S3	N
2	3541.75	S1	S1	S1	S1	S3	S2	S3	S2	S1	S3	S3p.t.sl
3	572.37	S1	S1	S1	S1	S3	S2	S3	S1	S1	S2	S3p.t
4	338.30	S1	S1	S1	S1	N	S2	S1	S2	S1	S2	N
5	154.32	S1	S1	S1	S1	N	S2	S3	S2	S2	N	N
6	552.27	S1	S1	S1	S1	S3	S2	S1	S2	S1	S3	S3p.sl
7	303.66	S1	S1	S1	S1	S3	S2	S3	S2	S2	S3	S3p.t.sl
8	29.35	S1	S1	S1	S1	S3	S1	S3	S3	S1	S3	S3p.t.d.sl
9	221.16	S1	S1	S1	S1	S3	S1	S3	S2	S1	S2	S3p.t
10	2834.24	S1	S1	S1	S1	S2	S1	S1	S1	S2	S1	S2
11	144.10	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
12	32.50	S1	S1	S1	S1	S2	S1	S3	S2	S1	S1	S3t
13	178.36	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
14	109.87	S1	S1	S1	S1	N	S1	S1	S2	S2	S2	N
15	7.61	S1	S1	S1	S1	S3	S1	S3	S2	S2	N	S3p.t
16	193.55	S1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3t
17	71.69	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
18	43.12	S1	S1	S1	S1	S2	S1	S1	S2	S1	S2	S2
19	134.25	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
20	81.96	S1	S1	S1	S1	S3	S1	S3	S2	S1	S2	S3p.t
21	45.47	S1	S1	S1	S1	S2	S2	S3	S2	S2	N	S3t
22	118.55	S1	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3p.t
23	12.48	S1	S1	S1	S1	S2	S1	S2	S1	S1	S2	S2
24	642.40	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
25	89.69	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
26	41.64	S1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3p
27	102.02	S1	S1	S1	S1	S2	S2	S1	S1	S1	S1	S2
28	128.71	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p
29	75.65	S1	S1	S1	S1	S2	S1	S3	S3	S1	S2	S3t.d
30	2.50	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
31	14.76	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
32	21.32	S1	S1	S1	S1	S3	S1	S3	S3	S1	S2	S3p.t.d
33	38.82	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
34	58.75	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
35	19.52	S1	S1	S1	S1	S3	S1	S2	S1	S1	S1	S3p
36	38.64	S1	S1	S1	S1	S2	S1	S2	S1	S1	S2	S2
37	137.24	S1	S1	S1	S1	S3	S1	S3	S2	S1	S1	S3p.t
38	86.34	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p
39	3.170	S1	S1	S1	S1	S3	S1	S1	S2	S1	S3	S3p.sl
40	179.569	S1	S1	S1	S1	S3	S1	S1	S1	S2	S1	S3p
41	44.719	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2
42	136.646	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p

43	84.606	S1	S1	S1	S1	S3	S1	S1	S2	S1	S2	S3p
44	2424.038	S1	S1	S1	S1	S2	S2	S3	S2	S1	S3	S3t
45	35.400	S1	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3p.t
46	23.053	S1	S1	S1	S1	S2	S2	N	S3	S1	S3	S3d.sl
47	102.760	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
48	1531.503	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
49	858.522	S1	S1	S1	S1	S2	S2	S1	S2	S1	S2	S2
50	522.041	S1	S1	S1	S1	S3	S1	S2	S1	S1	S1	S3p
51	473.766	S1	S1	S1	S1	S2	S1	S1	S2	S1	S2	S2
52	34.467	S1	S1	S1	S1	S3	S1	S2	S1	S1	S1	S3p
53	94.478	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
54	12.798	S1	S1	S1	S1	S2	S1	S2	S1	S1	S2	S2
55	735.649	S1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3t
56	55.872	S1	S1	S1	S1	S3	S1	S2	S1	S1	S1	S3p
57	58.905	S1	S1	S1	S1	N	S1	S2	S1	S1	S1	N
58	6.978	S1	S1	S1	S1	S2	S1	S2	S1	S1	S1	S2
59	30.318	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3p
60	92.442	S1	S1	S1	S1	S2	S1	S2	S1	S1	S2	S2
61	516.945	S1	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3p.t
62	107.207	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3p
63	436.544	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3p
64	3.691	S1	S1	S1	S1	S3	S1	N	S2	S2	S3	N
65	113.046	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3p
66	78.675	S1	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3p.t
67	43.349	S1	S1	S1	S1	S2	S1	S2	S1	S1	S2	S2
68	293.839	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
69	22.514	S1	S1	S1	S1	S3	S1	S3	S1	S1	S2	S3p.t
70	111.046	S1	S1	S1	S1	S2	S1	S3	S1	S1	S2	S3t
71	522.129	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p
72	141.200	S1	S1	S1	S1	S3	S1	S3	S3	S1	S2	S3p.t.d
73	85.247	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2
74	68.607	S1	S1	S1	S1	S2	S1	S1	S2	S1	S2	S2
75	34.423	S1	S1	S1	S1	S2	S1	S1	S1	S1	S2	S2
76	914.398	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p
77	228.956	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p.sl
78	127.960	S1	S1	S1	S1	S3	S1	S2	S1	S1	S2	S3p
79	5.856	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
80	1.824	S1	S1	S1	S1	S2	S2	S3	S3	S1	S3	S3t.d.sl
81	47.784	S1	S1	S1	S1	S3	S1	S3	S2	S1	S3	S3p.t.sl
82	148.047	S1	S1	S1	S1	S3	S1	S1	S1	S1	S1	S3p
83	551.126	S1	S1	S1	S1	S3	S1	S1	S2	S1	S3	S3p.sl
84	62.004	S1	S1	S1	S1	S3	S1	S1	S1	S1	S2	S3p
85	82.213	S1	S1	S1	S1	S2	S1	N	S2	S1	N	N

Appendix Table: 13 Sub criteria of infrastructure and economic attributes

	MARKT	ROAD	VALUE	AGINPUT	IRIGN	R/C	*Weights*
MARKT	1	2	5	3	1/3	1/3	0.138
ROAD	1/2	1	6	2	1/2	1/2	0.148
VALUE	1/5	1/6	1	1/4	1/5	1/9	0.034
AGINPUT	1/3	1/2	4	1	1/3	1/2	0.096
IRIGN	3	2	5	3	1	2	0.322
R/C	3	2	9	2	1/2	1	0.262
Consistency Ratio (CR) = 0.027							

Appendix Table: 14. Sub criteria of the social attribute

	MINFO	MOTIV	CULTV	LABFR	CAPINV	*Weights*
MINFO	1	7	3	5	2	***0.440***
MOTIV	1/7	1	1/5	1/3	1/3	***0.048***
CULTV	1/3	5	1	2	3	***0.250***
LABFR	1/5	3	1/2	1	1/2	***0.104***
CAPINV	1/2	3	1/3	2	1	***0.159***
Consistency Ratio (CR) = 0.052						

Appendix Table: 15 Sub criteria of physical environment

	PHY	ERO	CRP	URB	*Weights*
PHY	1	6	5	7	***0.635***
ERO	1/6	1	1/3	1	***0.084***
CRP	1/5	3	1	3	***0.201***
URB	1/7	1	1/3	1	***0.080***
Consistency Ratio (CR) = 0.034					

Appendix table: 16 Suitability indexes of different sub-criteria for multi-criteria land suitability evaluation.

LU ID	AREA (Ha)	Si= ΣXi x Wi															Index (Si)	Suitability	
		Irign	road	value	Markt	Aginp	R/C	Minfo	Motiv	Cultv	Labfr	Capin	Phy	Ero	Crop	Urb		So-eco	Phy
1	13.07	0.98	0.32	0.11	0.36	0.29	0.91	0.20	0.04	0.14	0.07	0.06	0.00	0.37	0.69	0.35	4.9	N	N
2	3541.75	0.98	0.45	0.14	0.42	0.29	0.80	0.27	0.03	0.12	0.06	0.07	1.55	0.33	0.78	0.35	6.6	S3	S3a.t.sl
3	572.38	1.12	0.45	0.12	0.48	0.34	0.68	0.27	0.03	0.14	0.07	0.07	1.55	0.29	0.78	0.31	6.7	S3	S3t
4	338.31	0.70	0.38	0.11	0.36	0.29	0.91	0.27	0.03	0.14	0.06	0.06	0.00	0.29	0.69	0.35	4.6	N	N
5	154.32	0.84	0.32	0.11	0.30	0.25	0.91	0.24	0.04	0.14	0.06	0.07	0.00	0.37	0.69	0.35	4.7	N	N
6	552.28	1.12	0.51	0.11	0.48	0.29	0.80	0.27	0.03	0.18	0.06	0.08	1.55	0.29	0.78	0.23	6.8	S3	S3sl
7	303.67	0.98	0.51	0.09	0.42	0.29	0.91	0.20	0.03	0.14	0.07	0.06	1.55	0.33	0.69	0.35	6.6	S3	S3t. sl
8	29.35	1.26	0.58	0.11	0.48	0.34	0.80	0.31	0.04	0.12	0.06	0.10	1.55	0.33	0.88	0.23	7.2	S2	S3t.d.sl
9	221.16	1.12	0.45	0.09	0.48	0.34	0.91	0.24	0.04	0.14	0.06	0.08	1.55	0.29	0.69	0.27	6.7	S3	S3t
10	2834.24	1.26	0.58	0.12	0.54	0.38	0.80	0.27	0.02	0.16	0.04	0.10	2.78	0.33	0.69	0.20	8.3	S1	S1
11	144.11	1.12	0.45	0.09	0.42	0.29	0.80	0.24	0.03	0.16	0.06	0.07	2.16	0.25	0.69	0.23	7.1	S2	S2
12	32.51	0.98	0.45	0.09	0.48	0.25	0.91	0.24	0.03	0.14	0.06	0.08	1.55	0.25	0.69	0.23	6.4	S3	S3t
13	178.37	0.98	0.51	0.11	0.48	0.29	0.80	0.27	0.03	0.14	0.05	0.10	2.16	0.25	0.78	0.20	7.1	S2	S2
14	109.87	0.98	0.51	0.11	0.48	0.29	0.80	0.24	0.03	0.14	0.06	0.08	1.55	0.21	0.69	0.31	6.5	S3	S3p
15	7.61	0.84	0.32	0.09	0.42	0.29	0.91	0.24	0.03	0.12	0.07	0.07	0.00	0.25	0.59	0.35	4.6	N	N
16	193.56	1.26	0.51	0.11	0.54	0.29	0.91	0.27	0.02	0.14	0.05	0.10	1.55	0.25	0.69	0.20	6.9	S3	S3t
17	71.70	1.12	0.51	0.11	0.48	0.29	0.91	0.27	0.02	0.14	0.05	0.10	2.16	0.25	0.69	0.20	7.3	S2	S2
18	43.13	1.26	0.51	0.09	0.42	0.29	0.91	0.20	0.03	0.18	0.07	0.07	2.16	0.25	0.78	0.31	7.6	S2	S2
19	134.26	1.12	0.45	0.08	0.48	0.25	0.91	0.31	0.03	0.14	0.04	0.10	2.16	0.33	0.59	0.20	7.2	S2	S2
20	81.97	0.98	0.38	0.11	0.42	0.34	0.80	0.20	0.03	0.14	0.06	0.07	1.55	0.29	0.69	0.31	6.4	S3	S3p.t

21	45.48	0.84	0.32	0.09	0.36	0.29	0.91	0.20	0.03	0.14	0.07	0.06	0.00	0.29	0.59	0.35	4.5	N	N
22	118.55	1.12	0.51	0.11	0.42	0.29	0.91	0.24	0.04	0.14	0.06	0.07	1.55	0.29	0.59	0.31	6.6	S3	S3p.t
23	12.48	1.12	0.51	0.11	0.48	0.34	0.80	0.24	0.03	0.16	0.05	0.08	2.16	0.29	0.78	0.20	7.3	S2	S2
24	642.41	1.26	0.58	0.11	0.36	0.34	0.91	0.24	0.04	0.16	0.07	0.07	1.55	0.29	0.88	0.35	7.2	S2	S3p
25	89.69	1.26	0.45	0.09	0.42	0.29	0.91	0.24	0.03	0.14	0.07	0.08	1.55	0.21	0.59	0.35	6.7	S3	S3p
26	41.65	0.84	0.45	0.09	0.42	0.29	1.03	0.20	0.04	0.16	0.06	0.06	1.55	0.29	0.69	0.27	6.4	S3	S3t
27	102.03	1.26	0.58	0.11	0.42	0.29	0.80	0.17	0.03	0.18	0.06	0.06	2.16	0.29	0.49	0.20	7.1	S2	S2
28	128.71	0.98	0.58	0.09	0.42	0.34	0.91	0.24	0.03	0.14	0.07	0.08	1.55	0.29	0.88	0.35	6.9	S3	S3p
29	75.65	1.26	0.32	0.11	0.30	0.29	1.03	0.20	0.03	0.12	0.07	0.06	1.55	0.37	0.69	0.35	6.7	S3	S3t.d
30	2.51	1.26	0.58	0.08	0.48	0.29	0.57	0.24	0.02	0.14	0.04	0.08	1.55	0.29	0.69	0.20	6.5	S3	S3p
31	14.76	1.26	0.58	0.08	0.48	0.29	0.57	0.24	0.02	0.14	0.04	0.08	2.16	0.33	0.69	0.23	7.2	S2	S2
32	21.33	0.98	0.58	0.09	0.42	0.29	0.68	0.24	0.03	0.12	0.06	0.07	1.55	0.29	0.69	0.27	6.3	S3	S3p.d
33	38.82	0.98	0.58	0.08	0.54	0.29	0.80	0.17	0.03	0.14	0.05	0.08	1.55	0.21	0.69	0.27	6.4	S3	S3p
34	58.76	1.12	0.58	0.11	0.30	0.29	0.80	0.24	0.03	0.12	0.06	0.06	2.16	0.29	0.69	0.35	7.2	S2	S2
35	19.52	0.70	0.58	0.11	0.54	0.29	0.80	0.27	0.03	0.14	0.04	0.08	1.55	0.21	0.69	0.20	6.2	S3	S3p
36	38.64	0.70	0.51	0.11	0.54	0.29	0.80	0.27	0.03	0.14	0.04	0.08	2.16	0.25	0.69	0.20	6.8	S3	S2
37	137.24	1.26	0.58	0.11	0.36	0.34	0.91	0.24	0.04	0.16	0.07	0.07	1.55	0.29	0.78	0.35	7.1	S2	S3p.t
38	86.35	0.84	0.58	0.09	0.48	0.29	0.57	0.24	0.03	0.14	0.04	0.08	1.55	0.21	0.69	0.20	6.0	S3	S3p
39	0.00	1.26	0.45	0.11	0.48	0.25	1.03	0.24	0.04	0.14	0.06	0.06	1.55	0.21	0.69	0.27	6.8	S3	S3p.sl
40	179.57	0.98	0.58	0.08	0.42	0.38	0.80	0.24	0.04	0.14	0.04	0.08	1.55	0.29	0.69	0.35	6.6	S3	S3p
41	44.72	1.26	0.45	0.08	0.30	0.29	0.80	0.17	0.04	0.14	0.07	0.06	2.16	0.29	0.69	0.35	7.1	S2	S2
42	136.65	0.98	0.58	0.11	0.36	0.29	0.80	0.24	0.04	0.18	0.06	0.06	1.55	0.21	0.69	0.27	6.4	S3	S3p
43	84.61	0.70	0.58	0.14	0.54	0.29	0.68	0.27	0.03	0.14	0.04	0.08	1.55	0.29	0.69	0.27	6.3	S3	S3p
44	2424.04	0.70	0.45	0.14	0.54	0.29	0.80	0.31	0.04	0.14	0.06	0.08	1.55	0.37	0.78	0.27	6.5	S3	S3p.t.sl

45	35.40	0.98	0.58	0.11	0.36	0.29	0.80	0.24	0.04	0.18	0.06	0.06	1.55	0.29	0.69	0.35	6.6	S3	S3p.t
46	23.05	0.70	0.45	0.08	0.30	0.29	0.80	0.17	0.04	0.14	0.07	0.06	0.00	0.21	0.69	0.35	4.3	N	N
47	102.76	0.98	0.45	0.08	0.42	0.34	0.80	0.17	0.03	0.14	0.07	0.06	1.55	0.29	0.69	0.35	6.4	S3	S3p
48	1531.50	0.98	0.58	0.14	0.54	0.34	0.80	0.31	0.03	0.14	0.06	0.08	2.16	0.29	0.69	0.27	7.4	S2	S2
49	858.52	0.98	0.58	0.11	0.42	0.21	0.80	0.27	0.04	0.14	0.05	0.08	2.16	0.21	0.78	0.31	7.1	S2	S2
50	522.04	1.12	0.58	0.12	0.54	0.29	0.80	0.31	0.04	0.16	0.04	0.11	1.55	0.37	0.69	0.20	6.9	S3	S3p
51	473.77	0.70	0.58	0.09	0.54	0.29	0.80	0.24	0.02	0.14	0.06	0.06	2.16	0.29	0.69	0.20	6.8	S3	S2
52	34.47	0.84	0.58	0.09	0.54	0.29	0.80	0.24	0.03	0.14	0.04	0.08	1.55	0.33	0.59	0.20	6.3	S3	S3p
53	94.48	0.98	0.58	0.12	0.54	0.29	0.68	0.31	0.04	0.14	0.05	0.08	2.16	0.29	0.69	0.23	7.2	S2	S2
54	12.80	0.70	0.58	0.11	0.42	0.34	0.80	0.27	0.03	0.12	0.05	0.08	2.16	0.33	0.69	0.20	6.9	S3	S2
55	735.65	0.98	0.58	0.11	0.54	0.29	0.91	0.24	0.04	0.14	0.06	0.07	1.55	0.33	0.69	0.27	6.8	S3	S3t
56	55.87	0.70	0.58	0.12	0.48	0.29	0.80	0.24	0.04	0.12	0.04	0.07	1.55	0.33	0.69	0.27	6.3	S3	S3p
57	58.91	0.98	0.51	0.11	0.48	0.29	0.80	0.27	0.04	0.14	0.06	0.06	1.55	0.33	0.59	0.27	6.5	S3	S3p
58	6.98	1.26	0.58	0.12	0.54	0.29	0.68	0.27	0.04	0.18	0.04	0.08	2.16	0.37	0.69	0.20	7.5	S2	S2
59	30.32	1.12	0.45	0.11	0.48	0.29	0.91	0.24	0.04	0.14	0.06	0.07	1.55	0.33	0.69	0.31	6.8	S3	S3p
60	92.44	1.12	0.58	0.12	0.54	0.34	0.80	0.27	0.04	0.14	0.05	0.07	2.16	0.33	0.78	0.23	7.6	S2	S2
61	516.95	0.98	0.51	0.09	0.42	0.34	0.91	0.20	0.03	0.12	0.06	0.08	1.55	0.33	0.69	0.31	6.6	S3	S3p
62	107.21	0.84	0.45	0.12	0.48	0.34	0.80	0.31	0.03	0.14	0.06	0.07	1.55	0.37	0.78	0.31	6.6	S3	S3p
63	436.54	1.26	0.51	0.11	0.42	0.34	0.91	0.20	0.03	0.16	0.06	0.08	1.55	0.29	0.78	0.35	7.1	S2	S3p
64	3.69	0.98	0.45	0.11	0.42	0.34	0.91	0.20	0.03	0.14	0.07	0.07	1.55	0.21	0.69	0.27	6.4	S3	S3p
65	113.05	0.98	0.51	0.12	0.54	0.34	0.91	0.27	0.04	0.14	0.04	0.08	1.55	0.33	0.69	0.31	6.8	S3	S3p
66	78.68	0.70	0.45	0.11	0.42	0.29	0.91	0.17	0.03	0.14	0.04	0.08	1.55	0.29	0.69	0.20	6.1	S3	S3p.t
67	43.35	0.98	0.45	0.12	0.42	0.34	0.80	0.27	0.04	0.14	0.06	0.07	2.16	0.37	0.69	0.27	7.2	S2	S2
68	293.84	0.70	0.45	0.11	0.48	0.38	0.80	0.24	0.04	0.14	0.07	0.08	2.16	0.33	0.69	0.35	7.0	S2	S2

69	22.51	0.98	0.51	0.12	0.48	0.38	0.68	0.24	0.04	0.14	0.07	0.08	1.55	0.33	0.69	0.35	6.6	S3	S3p.t
70	111.05	0.98	0.58	0.11	0.48	0.34	0.68	0.27	0.03	0.12	0.06	0.10	2.16	0.29	0.69	0.20	7.1	S2	S2
71	522.13	0.70	0.45	0.11	0.42	0.34	0.91	0.24	0.03	0.14	0.06	0.07	1.55	0.25	0.69	0.31	6.3	S3	S3p
72	141.20	0.98	0.58	0.09	0.48	0.29	0.91	0.27	0.03	0.14	0.06	0.08	1.55	0.21	0.69	0.35	6.7	S3	S3p.t.d
73	85.25	0.70	0.58	0.11	0.48	0.29	0.80	0.20	0.03	0.14	0.05	0.07	2.16	0.37	0.69	0.27	6.9	S3	S2
74	68.61	0.98	0.45	0.14	0.48	0.29	0.80	0.31	0.04	0.14	0.06	0.08	2.16	0.37	0.69	0.35	7.3	S2	S2
75	34.42	0.98	0.58	0.11	0.42	0.34	0.68	0.24	0.02	0.14	0.05	0.06	2.16	0.33	0.69	0.23	7.0	S2	S2
76	914.40	1.26	0.45	0.11	0.48	0.34	0.91	0.24	0.04	0.14	0.06	0.06	1.55	0.29	0.69	0.35	6.9	S3	S3p
77	228.96	1.26	0.58	0.09	0.42	0.34	0.91	0.17	0.03	0.16	0.07	0.07	1.55	0.21	0.69	0.35	6.9	S3	S3p
78	127.96	1.12	0.58	0.09	0.42	0.29	0.80	0.24	0.03	0.14	0.06	0.07	1.55	0.29	0.78	0.31	6.8	S3	S3p
79	5.86	0.84	0.51	0.11	0.42	0.34	0.91	0.24	0.03	0.14	0.05	0.06	1.55	0.25	0.69	0.31	6.4	S3	S3p
80	1.82	0.70	0.45	0.09	0.36	0.34	0.80	0.20	0.03	0.14	0.07	0.06	1.55	0.37	0.69	0.35	6.2	S3	S3t.d.sl
81	47.78	0.98	0.45	0.09	0.42	0.29	0.80	0.24	0.03	0.14	0.06	0.07	1.55	0.33	0.69	0.35	6.5	S3	S3p.t.sl
82	148.05	1.26	0.45	0.11	0.42	0.34	0.91	0.20	0.04	0.14	0.07	0.06	1.55	0.37	0.69	0.35	6.9	S3	S3p
83	551.13	0.70	0.38	0.09	0.42	0.29	0.91	0.20	0.04	0.14	0.07	0.06	1.55	0.21	0.59	0.35	6.0	S3	S3p.sl
84	62.00	0.98	0.51	0.09	0.42	0.29	0.80	0.24	0.03	0.14	0.06	0.07	1.55	0.29	0.69	0.31	6.5	S3	S3p
85	82.21	0.70	0.32	0.09	0.36	0.34	0.91	0.20	0.04	0.14	0.07	0.06	0.00	0.21	0.59	0.35	4.4	N	N

Appendix Box: 1 Details of land attributes for LIS database generation:

1. Attribute name	: Attribute-ID
Description	: ID for the profile layer attribute that was analyzed
Field name	: AT_ID
Unit	: n/a
Data type	: Character
Field size	: 8
Values	: A integer value is assign to indicate each type of attributes
2. Attribute name	: Soil Taxonomy
Description	: The Soil Taxonomy classification for the soil profile as is indicated in the national database or relevant report. FAO-UNESCO name is assigned
Field name	: S_TAX
Required	: Yes
Unit	: n/a
Data type	: text
Field size	: 50
Values	: All valid (full) taxonomic names according to Soil Taxonomy
3. Attribute name	: Land use
Description	: Land use class (Remmelzwaal, 1990); a hierarchical system on the basis of the type of land use and the occurrence of input and/or output (animal products, crops)
Field name	: L_USE
Unit	: n/a
Data type	: text
Field size	: 3
Values	: All valid land use class codes in the Country Codes table

4. Attribute name : Total sand

Description : Weight % of particles 2.0-0.05 mm (sand) in fine earth fraction. The total sand fraction, as the sum of the subfractions.

Field name : SAND

Unit : percent

Data type : number

Field size : 4

Values : All integers between 0 and 100

5. Attribute name : Silt

Description : Weight% of particles 0.05-0.002 mm (silt) in fine earth fraction

Field name : SILT

Unit : percent

Data type : number

Field size : 4

Values : All integers between 0 and 100.

6. Attribute name : Clay

Description : Weight% of particles < 0.002 mm (clay) in fine earth fraction

Field name : CLAY

Unit : percent

Data type : number

Field size : 4

Values : All integers between 0 and 100.

7. Attribute name : Soil Texture

Description : The collective particle size class as derived from the particle size analysis results.

Field name : SOTEX

Unit : n/a

Data type : text

Field size : 6

Values : alphabetical representation for each of the texture classes of soil

S : Sand

SL : Sandy loam

SIL : Silty loam

L : Loam LC : loamy Clay SC : Sandy clay
8. Attribute name : Total nitrogen Description : The content of total N Field name : NITRO Unit : % Data type : Decimal Field size : 6 Values : all floating numbers equal to, or greater than, zero, with a precision of at least 1 digit
9. Attribute name : P2O5 Description : The P2O5 content Field name : PHOS Unit : Kg/ha Data type : Decimal Field size : 6 Values : All integers equal to, or greater than, zero
10. Attribute name : Soil Reaction (pH) Description : The pH as determined in the supernatant suspension of a 1:2.5 soil-water mixture Field name : PH Unit : Data type : float Field size : 6 Values : A floating number equal to, or greater than, 0, with a precision of at least 1 digit
11. Attribute name : POTA Description : The potassium content in the soil Field name : K Unit : kg/ha Data type : Decimal Field size : 6 Values : All integers equal to, or greater than, zero

12. Attribute name : Water Holding Capacity Description : The amount of water absorbed by unit weight of soil in given period of time. This related with particle size Field name : WHC Unit : Percent Data type : Decimal Field size : 4 Values : All integers between 0 and 100
13. Attribute name : Organic matter Description : Litter or organic matter on the surface, described after thicknes (in cm) and degree of decomposition (Soil Survey Staff, 1975) Field name : OM Unit : Percent Data type : Decimal Field size : 4 Values : all the numerical values starting from 0
14. Attribute name : Degree of erosion Description : Degree of erosion in classes after FAO (1990) Field name : ERO Unit : n/a Data type : text Field size : 1 Values : As designated types as follows S : Slight M : Moderate V : Severe E : Extreme
15. Attribute name : Soil Rootable depth Description : Estimated depth to which root growth is unrestricted by physical or chemical impediments - in classes after FAO (1990) Field name : DEPTH Unit : cm Data type : text Field size : 1

Values

V : Very shallow (< 30 cm) & (30-55 cm)

S : Shallow (55-80 cm)

M : Moderately deep (80-100 cm)

D : Deep (100-120 cm)

X : Very deep (> 120 cm)

Appendix box: 2 Future Plan of Vegetable Development Program

Government of Nepal

National Planning Commission

Future plan of Vegetable Development Program

Concept:

Constant increase in demand over vegetable attributed by increasing population, awareness on food and nutrition, industrialization and urbanization, increment in GDP, export promotion, etc. Similarly, transportation facilities, marketing network, production technology, improved seed accessibility, application of fertilizers and pesticides are responsible for the increased supply of the fresh vegetable else where in country. Vegetable cultivation is income generating and labor intensive activities, this generate employment opportunity and economic benefit to the small farmers in rural areas, nutritional security. Continuous increased supplies of vegetables will guarantee nutritional security.

Objective of the three year future plan of vegetable sector

To enhance the fresh vegetable production and productivity for

a. Nutritional supplement

b. Strengthening local agro-business in the rural area

c. Economic benefits to the poor and under privileged farmers.

d. Contribution to the environmental conservation

Pocket Areas

Future plan identifies following pocket areas for vegetable cultivation according to physiographic zones of Nepal as given in following table.

Physiographic zone	Development Region	Potato, vegetable and spice development program
High Himal		Potato from seed, Alaichi, Capsicum, off-season fresh vegetable production, vegetable seed production
Middle Mountain		Khayan Potato, Potato from seed, Cardomom, Akware Capsicum, Export oriented vegetable and vegetable seed production
	Kathmandu Valley	Akbare Capsicum, Khayan Potato, Export quality off-seasonal and seasonal Organic vegetable farming
Terai		Potato from seed, Potato with tubers, Khayan Potato, Zinger, Off-seasonal vegetable for export, vegetable seed production

Procedure for program implementation

Production program has been categorized as

a. commercial fresh vegetable production (for domestic market)

b. Fresh vegetable production for the export (For external markets)

c. General fresh vegetable production (For household consumption)

Vegetable seed development program

- Development of the seed selection or genetic development Germplasm identification and registration of the plant used as vegetable in Nepal.
- Improvement over the traditional knowledge and technique about cultivation and consumption of fresh vegetable in Nepal
- Horticulture farms are to be categorized according to the Agri-ecological zone and assign full responsibility on the research and development of the specific vegetables and spice of the very ecological zone.

SN	Article	Unit	Base yr.	059/60 (2003)		060/61 (2004)		061/62 (2005)		062/63 (2006)		Growth (%) base yr.
				Goal	Success	Goal	Success	Goal	Success	Goal	Success	
	Fresh Vegetables											
1	Area	ha	161048	164926	165988	173073	172586	181623	180823	190595	190597	18.35
2	Production	Mt	1738086	1767365	1799973	1889667	1890100	2020432	2065193	2160246	2185193	25.72
3	Productivity	Mt/ha	10.7	10.69	10.84	10.92	10.95	11.11	11.42	11.31	11.46	7.10
	Spice											

Problems and limitations of the tenth plan

7. Lack of the human resources
8. Difficult to have right man at right palace
9. Lack of institutional reform and improper coordination up to bottom level
10. Insufficient budget
11. Lack of Infrastructural reforms
12. Seed production has been affected due to the lack of sufficient budget
13. Tough National situation

Forth coming three year plan and its goal

SN	Particular	Unit	Base year 062/63 (2006)	064/65 (2008) Target	065/66 (2009) Target	066/67 (2010) Target	Growth (%) on base year
Fresh Vegetables							
1	Area	ha	189832	209550	219965	232540	22.00
2	Production	Mt	2190100	2430780	25669911	2790480	25.41
3	Productivity	Mt/ha	11.51	11.60	11.67	12	4.0

Policies

1.1 Specific vegetable cultivation will be promoted on the basis of comparative profit and physiographic region. Rural poverty will be expected to recede down through promotion and commercialization of vegetable, potato, spice and tuber crops.

2.1 To emphasize on generation of competitive capability of the farmers

3.1 Put emphasis on enhancement of higher level and field level technical man power so that effective services can be delivered promptly.

4.1 Inclusion of gender, ethnic concept in the program

Strategy

e) Increase on vegetable consumption to support on nutritional security of the people
f) Emphasis on intensive farming rather than in extension of the land area
g) Put emphasis on commercialization of vegetable cultivation
h) To export fresh organic vegetable
i) Identification and allocation of the export pocket are of the vegetable cultivation for export.
j) Diversification of the agriculture according to agro-ecological zones of Nepal
k) Establishment of the commercial nurseries
l) Extension of agriculture research and development centers in the country
m) Reduction in the application of the pesticides and harmful toxic materials
n) Promote private sector for the seed production export
o) Promote hybrid seed production
p) Prime importance should be given to those pocket areas where only export varieties of the vegetable seed will be produced.
q) To enhance commercial capability of the vegetable, packaging and labeling of the sell

r) Constant monitoring of the vegetable production and development program

Working policies

- Fresh vegetable production program is to be conducted on two categories namely commercial and ordinary
- Arrangements will be made to produce off season vegetables like production in plastic tunnel.
- Organic vegetables production are to be conducted on categorized manner
- Vegetable markets and production sites are to be arranged according to available road network.
- Export pocket area will be furnished with the cultivation of specified vegetable varieties
- Promotion of kitchen gardening for the production of fresh vegetable round the year is arranged in the area with lack of adequate transportation facilities and market channel.
- Agricultural research will be coordinated with the established research institutions.
- Existing agriculture farm and centers are used to promote research, investigations, hybridization and so on.
- Integrated Pest Management (IPM) program will be emphasized to reduce use of insecticides.
- Government organizations are to collaborate with private sector for the production of the high yielding hybrid varieties.
- Evaluation of vegetable seed will be done in every two years
- Keeping buffer stock of the seed will be institutionalized.
- Construction and handing over of seed processing and testing lab and store to the farmers of the pocket area where production is fairly high enough to enhance export quantity.
- Regular and effective technical support will be offered at doorstep.
- Long term and short term training to farmers and workers will be conducted.
- Gender issues is to be consider for effective implementation of the program

Vegetable policies

Demand and supply projections

A major effort was made recently to project the demand and supply of vegetables and potato for the country to the year 2010. The Master Plan for Horticulture Development was prepared in 1991 by Pacific Management Resources Inc., USA, and the East Consult (P) Ltd, Nepal, for the Government of Nepal and the Asian Development Bank. This study estimated current per capita consumption levels for subsistence and commercial consumers for 28 individual vegetable species. Assumptions were made about changes in consumption patterns associated with a shift toward urban living and cash economy and about population growth. Using these data, production targets were computed and various strategies and programs were identified to achieve the production targets.

Input subsidy policy

The government provides price and transportation subsidies on fertilizer with the objective of increasing food production through lowering farmers' costs. However, Agricultural Input Corporation is unable to import enough fertilizer to meet farmers' demand. In addition, continuation of the subsidy encourages unauthorized cross-border movement of fertilizer (Wallace 1986; Crown Agents 199 1). Government of Nepal provides a transportation subsidy for remote Hill districts. Various studies have shown that the availability of fertilizer is a greater constraint than is price.

Underdeveloped markets for inputs

Distribution systems and markets for fertilizers, pesticides, seeds, and other inputs are well established in Kathmandu valley but perfect coordination is still to be set. In the absence of a good network of dealers and cooperatives, farmers have to travel long distances to purchase these inputs. Moreover, inputs are not available at the right time and in the quantities required.

Lack of credit

Studies show that only **24%** of the farm families who took loans, obtain them from institutional sources, where as rest have to use the non-formal sector (NRB 1980). Among those who borrow from institutional sources, large farmers have better access to such credit than small and marginal farmers. Time consuming procedure and provision are situations which require simplification.

Poor irrigation facilities

Most of the farmers have used groundwater schemes, particularly shallow tube wells, for vegetable production. New and buildup irrigation channels are not distributed through out the area however traditional channels, called Raj-Kulo become worn out, which was not maintained. No proper mapping and maintenance program has been put forward

Shortage of good quality seeds

Climatically adapted and disease-free seeds or seedlings are not usually available in Kathmandu. Many studies have shown that seed production in Nepal is profitable. However, seed production has been limited due to several constraints, including an unfavorable policy environment. There is a need for comprehensive study about the requirement of the seed for the specific region needs to be done. Then the action should be initiated to alleviate these constraints.

Support for the cold storage industry

Poor performance of the cold storage in the Kathmandu valley is the result not only of technical factors, such as design and construction defects and the small size of operations, but also of government policies. For example: cold stores in Nepal are listed as industries and do not qualify for the special provisions given to agro-based industries, such as tax holidays, low interest rates, and lower electricity tariffs. Electricity charges for cold storage do not take into account off-peak-hour facilities. The system needs to be developed.

Trade restrictions

Although the Municipality Act of 1992 clearly specifies that agricultural produce brought into municipal areas for commercial purposes is to be charged in total at 1% of the value of the goods, some municipalities are charging different rates. These lead to unnecessary cost and delay. Vegetable exports from Nepal are subjected to ad hoc valuation and exporters face harassment by municipal authorities because such supplies do not possess official valuation papers, unlike supplies coming from India which carry official receipts given by customs offices.

Pesticide regulations

Studies show that there is indiscriminate and heavy use of broad-spectrum pesticides on vegetable crops all over Nepal (Baker and Gyawali 1994). Farmers continue to use dangerous chemicals, such as organochlorines and organophosphates. According to a survey of farmers who had been using pesticides for over five years, more than 60% waited less than two weeks between spraying and harvesting the crop. This has led to increased health hazards, particularly in urban areas like Kathmandu valley. On the production front, regular misuse of broad-spectrum pesticides has resulted in resistance of pests to pesticides, resurgence of pests, and secondary pest outbreaks. However, the government enacted the Pesticides Act in 1992, and the Act has been promulgated. An effective implementation of the act is an urgent need in the Kathmandu valley and suburb areas.

Exchange rate policy

Nepal has a floating exchange rate with other currencies, but a fixed exchange rate with the Indian currency. Higher inflation and lower growth in factor productivity in Nepal compared to India is making Nepal's exports to India uncompetitive (Sharma 1994). On the other hand, Indian agricultural products, including fresh vegetables, are competing with Nepali produce in Nepali markets. The uncontrolled flow of about 14% of total vegetable entered in Kathmandu valley from India results in un-remunerative farm-gate prices of vegetables in Nepal, particularly during peak production. On the other hand, off-season supplies mostly come from India, and fetch good prices in Nepal.

Inadequate marketing support system

There has to be good extension system for the dissemination information regarding new production technology to farmers, post-production aspects, information on markets, volume of arrivals or prices offered, and development of a support system, etc. (Pun 1987This has resulted in an inefficient market system, where marketing margins are excessive and losses in the system are enormous. The government should work as a facilitator in creating infrastructure and in providing market information to mitigate these problems.

Future Research Priorities

Biophysical research

Several studies have identified important biophysical research priorities for Nepal (Rekhi et al. 1990; Shah 1990). Some of these priorities are:

1. Breeding of varieties suitable for the different farming systems in Nepal
2. Improvement of traditional vegetables so far neglected by the national and international research systems
3. Development of appropriate post-harvest and processing technologies
4. Production of high-quality seeds both for domestic and export markets
5. Collection, conservation, and utilization of local genetic resources
6. Development of varieties suitable for off-season vegetable production
7. Development of crop production technologies with emphasis on the time and method of planting, plant production, weed control, fertilizer management, and pest control
8. Species purification and maintenance.

STATEMENT OF ORIGINALITY

This dissertation report submitted to the Faculty of Agriculture and Horticulture at Humboldt University of Berlin for fulfillment of the requirements for the degree of PhD of Science in Agriculture is the original work of the author, except as otherwise stated. I declare that this has not been previously submitted for similar degree to any university. I therefore, certify that although I may have conferred with others in preparing for this assignment and drawn upon a range of sources cited in this work, the content of this thesis report is my original work.

…………………….

Nabarath Baniya

Berlin, July 2008